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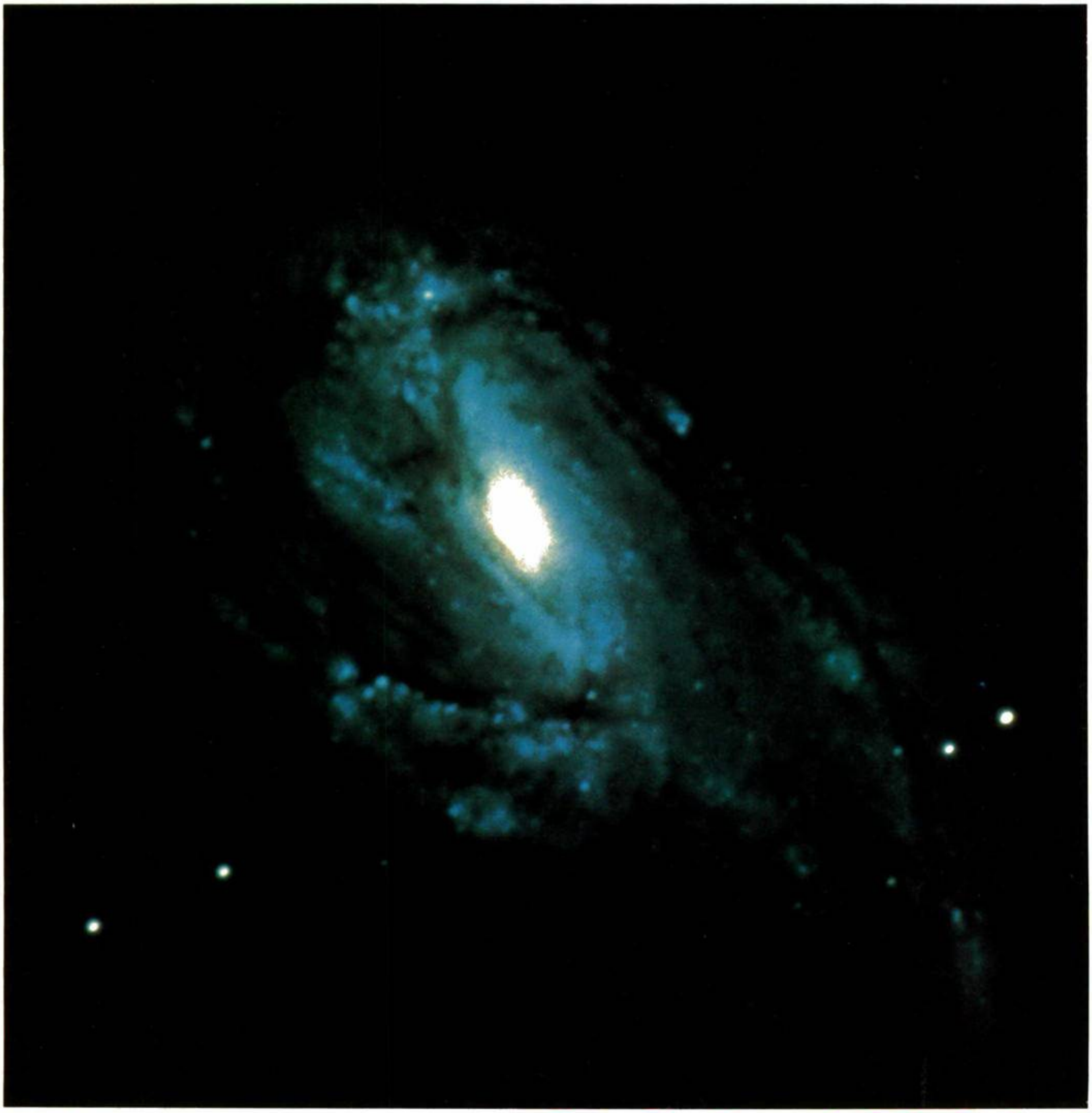

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Meade WIDE-FIELD
f/6.3 SCHMIDT–CASSEGR
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Init
Mode
Set
RA 23:58
DEC -35.6
N
W
E
S
∞
Focus
Near
2X
8X
Map
Quartz
Manual
Solar
Sidereal
Lunar
Reticle Adjust
U.S.A.
MEADE
MICROPROCESSOR CONTROLLED
LX QUARTZ PULSE DRIVE
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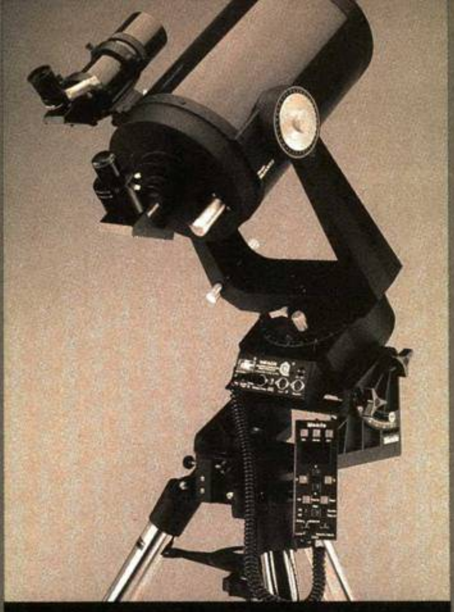
User Reports on the LX6 Revolution


Meade 8″ Model 2080/LX6

"Recently at a club star party we had the opportunity to test the Meade 10″ Model 2120/LX6 telescope. The first object observed was Jupiter, at 182X with the Meade Ultra Wide Angle 8.8mm eyepiece. Six cloud belts, as well as the Great Red Spot, were visible in great detail. I also observed a large festoon on the North Temperate Zone. Sharpness and contrast were equal to, if not better than, conventional f/10 optics. After simple polar alignment, the LX6 quartz drive tracked perfectly at high power. The view of the Orion Nebula (M42) was spectacular! The trapezium stars were sharp, bright pinpoints and the nebulosity overflowed the field of view in my Super Wide Angle 40mm eyepiece. The full extent of the Rosette Nebula (NGC 2237) was easily visible, and the Christmas Tree Nebula (NGC 2024) was an easy target for the f/6.3 optics. Even the Horsehead Nebula (IC 434) was seen visually with a nebular filter—the first time we had ever seen the Horsehead through a 10″ telescope. Other club members were equally impressed. Everyone commented on the ease of use and features of the LX6 handheld Electronic Command Center. Enclosed are two photos taken with the LX6 and the Meade Off-Axis Guider. The M42 photo is a 5 minute exposure, the Horsehead a 7-minute exposure. I am thrilled with the results and look forward to taking more astrophotographs with the Meade 2120/LX6."—***Douglas Finch,*** Birmingham, AL, Amateur Astronomer/Retail Telescope Store Manager.

"I took a Meade 10″ LX6 to the annual Southern Cross Winter Star Party in the Florida Keys in February. Since the instrument was new, I figured I would use the time as a good "shakedown." Starting out, I was impressed that, using the Meade 40mm Super Wide Angle eyepiece, the contrast was excellent—in fact, good enough to allow viewing of the fringe nebulosity portion of M42, areas which I have previously only known through photographs. Equally impressive was the Meade CAT Computer Aided Telescope system. While some amateurs around me were wondering whether NGC 3372 was sufficiently above the horizon to be seen, all I had to do was punch in its CNGC number on the CAT console and was guided precisely to the object. Although low on the horizon, the "keyhole" of NGC 3372 was easily seen. The CAT told me exactly where to look and I suspect I was the first one to see it. Of all the telescopes which I have used over the years, I am most impressed with the Meade 2120/LX6 with CAT computer system."—***Jim Brown,*** Atlanta, GA, Amateur Astronomer/Past President of the Astronomical League.

"I was frankly skeptical that your new 10″ f/6.3 optics could be as good as you claim, but several weeks of testing the 2120/LX6 side by side with other f/10 SCT's (including several competitive models) have fully validated everything you say. Using my Meade Ultra Wide Angle 8.8mm eyepiece at 182X, I obtained an image of Mars I thought possible only with long focal length refractors. And, as you state in your catalog, using wide angle eyepieces with the LX6 on star fields and nebulae permits a visual experience impossible to achieve with f/10 Schmidt-Cassegrains. I never thought I would see the day when a 10″ SCT yields an actual, fully corrected field 1.7° in diameter! As a serious observer of more than 20 years standing, I could not be more pleased with the instrument." ***Paul Hobbs,*** Monrovia, CA, Amateur Astronomer.

"After my first few times using an 8″ LX6, I think it is a VERY impressive telescope. When a friend and I took one out several weeks ago for the first time and pointed it at Jupiter, after allowing the instrument to reach ambient temperature, the LX6, notwithstanding its much wider field of view, compared very favorably with f/10 SCT's with respect to contrast and image quality. In addition, my friend took his first deep-sky shot on that night and in about a minute using Konica 3200 film got one heck of a shot of M42."—***Mark Saperstein,*** Boston, MA, Amateur Astronomer/Advertising Manager for optical specialty store.

"I previously have written to you about the excellent optics of your Series 4000 eyepieces and, after testing your new 10″ Model 2120/LX6, I am compelled to write again. In one sentence: the 2120/LX6 is the most impressive commercial instrument I have yet seen. Under critical examinations, stellar diffraction patterns are superb both inside and outside of focus. The telescope's optical quality compares very favorably with large professional instruments, including a 12″ Zeiss refractor and the 24″ Clark refractor at Lowell Observatory, that I have used in over 35 years of professional work as a staff astronomer. Focal images are sharp and crisp; in applications where high contrast characteristics are important (such as in observing the "eyes" of the Owl Nebula, M97, or structural variations in the main spiral arm of the Whirlpool Galaxy, M51), the 2120/LX6 performs impressively. The image of Saturn is beautifully defined, showing subtle belt detail and the crepe ring with surprising boldness for a 10″ telescope. The LX drive and control system is everything claimed. During an M51 exposure, it was possible for me to leave my observatory, pour myself a cup of coffee and return several minutes later to find the guide star still positioned on the crosshairs of my guiding eyepiece. The telescope's fast f/6.3 optics, combined with the LX6 electronic control system, add a professional dimension to the skilled observer's investigations. I would strongly recommend the Meade 2120/LX6 to anyone."—***Paul Roques,*** Williams, AZ, Professional Astronomer.

"On the night of January 29, 1989, under the clear, dark skies at Star Hill Inn, three members of the Lehigh Valley Astronomical Society from Pennsylvania, who were guests at Star Hill, and I were observing with a Meade 8″ LX6 and one of your 32mm Super Wide Angle eyepieces. To our amazement, we were able to detect, without a nebular filter, the Horsehead Nebula visually . . . quite a feat for an 8″ telescope! In addition we observed that M33 exhibited notable spiral structure. Again, very commendable for an 8″ telescope. That night, we all agreed that we had seen objects and detail in the 8″ LX6 that are normally reserved for 10″ and larger apertures. Among our rental equipment at Star Hill Inn is a Meade 10″ LX6 and we have been equally pleased with its performance. To sum it up, I think the Meade 8″ and 10″ LX6 models are outstanding instruments. Congratulations!"—***Phil Mahon,*** Sapello, NM, Owner, Star Hill Inn astronomical retreat.

"I purchased one of your 10″ Model 2120/LX6 telescopes late in 1988. Having access to a range of telescopes of various apertures, I am astonished that my 2120/LX6 can outperform instruments with significantly larger diameter. The common thread of my observations with the LX6 has been the ability to see diffuse nebulosity and filamentary detail that I've never before witnessed, except in photographs or through telescopes with over twice the aperture. Being able to discriminate such fine detail in faint objects could only be attributable to the superb contrast of the LX6 optical system. It is obvious the system is baffled for optimum contrast. As to some specific objects observed:

The Pleiades—Using the Super Wide Angle 40mm eyepiece with averted vision, I could see the curved filamentary structure around the main stars—something I've only seen in pictures before—plus vivid blueness in the four main stars.

Crab Nebula—With the Meade Ultra Wide Angle 14mm eyepiece, a very easy ability to observe the filamentary structure—my first time seeing this detail other than through a 24″ instrument.

Veil Nebula—Extremely easy to observe—the best I've ever seen it. Lucid wide bright area narrowing down to smaller nebulosity.

Galaxy M82—I have never seen the filamentary dust lanes as well in a 10″-aperture telescope.

Christmas Tree Nebula—was an easy subject, as was the *Rosette Nebula*."—***Brad Brotherton,*** Milwaukie, OR, Amateur Astronomer.

Call or visit your Meade dealer now for further details and prompt delivery of the Meade 8″ Model 2080/LX6 or 10″ Model 2120/LX6.

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ON THE COVER:
M66 in Leo is either 22 million or 76 million light-years away, depending on whose galactic distance scale you use. (See page 48.)

THE CLUMPY spiral arms of M63 in Canes Venatici were captured by Kim Zussman, a veteran astrophotographer who has found the secret to taking great deep-sky photos. (See page 68.)

ASTRONOMY®

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Behind the Scenes

TAKING UP THE CHALLENGE

An observer I know drives miles of icy mountain roads, lugs a heavy telescope through waist-deep snow, and digs out his observing pad — all to take pictures all night in the freezing cold.

What does he get out of it?

Another observer, who long ago saw all of the Messier objects, has set out to see the entire NGC catalog. She's several thousand objects into the project and collecting them by the hundred.

What does she get out of it?

The photographs and observations of these two observers won't change the world. Nor will science come an inch closer to understanding the origin of Earth or calibrating the cosmic distance scale as a result of their activities.

But who says you have to change the world? Who says you have to produce scientific results? Who says you have to observe at all? But if you want to observe, we can help you. This issue of ASTRONOMY offers three projects that will challenge you and bring you satisfaction. You can even make useful scientific observations, if that's what you feel like doing.

On July 3, Saturn will pass in front of the 6th-magnitude star 28 Sagittarii. For three hours, Saturn's rings will filter the light from this star, which will brighten and dim according to how opaque the rings are.

Voyager discovered that Saturn's three broad rings consist of hundreds of fine ringlets. The brightness of 28 Sagittarii should bounce up and down, tracing out a profile of ring density. Will it? I asked Jeff Kanipe to explain this unique observing opportunity. His story begins on page 80.

Another exciting project is to observe the satellites of the outer planets. It's not easy: they're dim and low in the sky for most North American observers. Pit your skills against Neptune's satellite Triton and see it before *Voyager* gets there. Rich Talcott's observing guide starts on page 74.

Do you know anyone who's seen a dark nebula? In this month's Backyard Astronomer (page 86), David Higgins shows how you can see them. The next time you're under dark skies, give dark nebulae a try.

If you take up the challenge, you'll be amazed at what you can see, and you'll understand what observers get out of observing.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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U.S. Newsstand Distribution
I.C.D., The Hearst Corp., New York, NY 10019

Canadian Newsstand Distribution
Telemedia Dist., Toronto, Ontario M4S 3B3

World Newsstand Distribution
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Letters

More Astronomy in the Media

Very little astronomy is reported in the mass media. One reason for this absence may be that professionals in the field do little to make themselves and their stories available to the press. The exception is the rare press release that announces a new discovery or theory.

Astronomers should make themselves more available to the public and discuss subjects that are common knowledge in the field in addition to new discoveries. What may be mundane to the professional could be of great interest to the general public.

Another step would be for observatories to expand their public relations departments. If more media attention was given to observatories and astronomical research projects, perhaps the public would encourage their elected officials to be more generous with funding. — *Roald Steen, Woodbury, Minnesota*

Mirror Maladies

I am an instructor in mirror grinding and telescope making and have a few comments about your article "Sharpen Images with a Cardboard Mask" by M. Leon Knott (February 1989).

I agree that masks can help mediocre mirrors and that most commercially made mirrors have some defects. But these defects cannot be eliminated or even minimized by "rotating the mirror until a good section of the mirror lies within the light path" as Mr. Knott states. In 99.9 percent of the cases, the bad zones in a mirror or a lens lie concentric with the edge of the optical element itself.

I have tested a lot of commercial optics and have found only one pair that had an acentric defect in its curve. A handful of mirrors were perfect, and the rest had minor to very serious concentric defects. — *Chris Baetens, Boechout, Belgium*

Crater Creation Controversy

I question Michael Kitt's deduction that the lunar craters Messier and Messier A were formed by the impact of a single meteor ("Eight Lunar Wonders," March 1989).

Messier A is larger and deeper than Messier; it seems that the reverse should be true. Unless surface composition is very different at both sites, the second impact should have had less force than the first, thus forming a smaller crater rather than a larger one.

Also, the distance between the craters does not support the ricochet theory. The *rebound should* have put the second impact some distance from the first.

Given the visible evidence, it seems much more likely that the two craters

DEAR MR. NAGLER:

Several years ago, I purchased a 10" Schmidt-Cassegrain telescope. On this new instrument, I carefully compared the performance of the most respected brands of eyepieces before concluding that the **Tele Vue** Plössls were giving me the best views. Along with 4 of your Plössls (55, 26, 17 and 13mm) and your 2.5x Barlow, I bought a Giant Off-Axis Guider, which I frequently use as a telecompressor. Although I have always been pleased with your eyepieces, there are limits to just how much a long-focal-length telescope can be telecompressed! ■

For over three years, I have wanted a second instrument for rich-field observing and photographing. Although your **Renaissance** is most impressive, it just wasn't quite the instrument I wanted and the **Oracle** was a bit too small. Then came **Genesis.** Knowing what a stickler you are for details in both design and production, plus my total satisfaction with your eyepieces; sight unseen, I bought a **Genesis** based solely on those facts and your ads in the magazines. ■

I took delivery of my **Genesis** at the Texas Astronomical Society's meeting on 7/22/88. Even with all the light pollution in that North Dallas parking lot, my new **Tele Vue** 32mm Wide Field eyepiece, at less than 16x, clearly resolved Saturn's rings as separate from the disc. When a friend asked to try his 12 mm Nagler-II with his 3x Barlow, I knew I had bought a "winner." The Cassini Division was as sharply defined as I have ever seen it plus the surface and ring detail was second only to a view I once saw under a Texas Star Party's dark skies through a nearly $20,000, 10.7" f/15 Maksutov! ■

The reason for this letter is simple. I have now had my first opportunity to take my new **Genesis** out to the T.A.S.'s dark-sky observing site (100 miles north of Dallas). In short order, the **Genesis** had attracted a group of experienced observers (most holding full Messier Certificates) away from their larger telescopes. Simply, **Genesis** stole the show! Except for an occasional comparison view, my 10" Schmidt-Cassegrain sat idle because I was seeing far greater clarity and detail with my new **Genesis.** Although I had with me a full set of filters (Deep Sky, U.H.C., O-III and H-β), none were ever used. ■

While I had anticipated a gorgeously resplendent Double Cluster, it was truly more dazzling than I expected. But, some real surprises lay ahead. Take M-33 in Triangulum: 4" just isn't enough aperture for such a diffuse spiral, right? WRONG! With the 32mm Wide Field, I was seeing tremendous detail in a galaxy over 1/3 the width of the field. I could write paragraphs describing a California Nebula covering half the field plus all the glorious sights through Sagittarius and Scorpius like the Lagoon, Trifid and M-21 all in the same field; or, four gleaming globulars, M-22 & 28 with NGC-6638 & 6642. ■

While the Great Andromeda Galaxy (M-31) spread across more than 2/3 of the field, we were all alternating time at the eyepiece, trying to see who could count the most dust lanes. It was more beautiful than even the photographs from the leading observatories. I have never seen M-110 appear as large relative to M-31. One observer even held his hand in front of the eyepiece and suggested that we try observing a projected image! While that may have been beyond even **Genesis'** capability, it does prove we were looking at no dim M-31. There was a debate over which eyepiece provided the better view: the 13mm Nagler's greater contrast and detail or the 32mm Wide Field's greater coverage. Each outperformed the other in its own way and both provided splendid views. ■

All night, comments from seasoned observers included a thesaurus-full of one word expletives of praise, wonder and astonishment. While glued to the eyepiece, other comments included: "... but this is ONLY a 4-inch" to "Boy! You sure made no mistake in buying this one" and "Oh, No!... How am I ever going to make my wife see the need?". One observer even yelled to a friend acoss the field, "Get over here if you want to see what Rich Field is SUPPOSED to look like." Personally, I can hardly wait to start taking astrophotos with it. ■

In case you could have possibly missed my point: I am totally enthralled with my new **Genesis.** Mr. Nagler, what you have created with your **Renaissance** and **Genesis** telescopes has filled a void, beyond binoculars and yet still permitting the beauty of deep sky objects to be viewed 'in context' without resorting to the usual solution of over-magnification that reveals detail at the expense of sacrificing perspective. ■

Because our dark sky observing location attracts late-night dewing and humidity, I appreciate your design consideration of including the fluorite element as a totally internal component, inaccessible to dew, condensation or scratches. ■

It would have been impolite of me not to write and tell you just how much of a Big Bang your **Genesis** telescope has already created in my deep sky observing. ■

Appreciatively yours,

Kent E. Ledlow

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resulted from separate meteor strikes. The proximity of the second meteor to the first could be happenstance, which is not unusual given the large number of meteor strikes across the Moon's surface. — *Emil L. Posey, Albertville, Alabama*

— Michael Kitt replies: Despite their apparent closeness when viewed through a telescope, Messier and Messier A are actually separated by almost fifteen miles. A fifteen-mile skip is within the realm of possibility for a projectile of the size required to form these craters. The precise axial alignment of Messier and Messier A makes it extremely unlikely that they resulted from unrelated meteor strikes.

Saturnian Meteorology

I am a professional meteorologist as well as an amateur astronomer, therefore, I was intrigued by the hexagon-pattern jet stream observed in Saturn's high northern latitudes (AstroNews, March 1989). The jet stream appears to be a low-amplitude, S-shaped planetary wave similar to those that occur in Earth's atmosphere. On Earth, however, a six-wave pattern would have too short a wavelength to remain stable; standing wave patterns on Earth typically have three or four waves.

Although the main heat source for Saturn's atmosphere is internal, the upper reaches of the atmosphere would undergo slow, but significant, seasonal changes in solar radiation because of Saturn's 30° axial tilt. These changes could cause a wave to develop to maximum intensity and amplitude in the hemisphere that is just emerging into spring, which was the northern hemisphere at the time of the *Voyager* encounters. Because one Saturnian "season" lasts over seven Earth years, a stable, upper-atmosphere wave pattern could persist for a very long time. — *S. W. Bieda Jr., Sierra Vista, Arizona*

Correction

The position of the Milky Way on the Sky Almanac map in the March 1989 and April 1989 issues was incorrect. The Milky Way should have been positioned on the right side of the map, not the left side.

ASTRONOMY welcomes comments, suggestions, corrections, and additional information on articles and astronomy. Send your letters to: ASTRONOMY Letters, 1027 North 7th Street, Milwaukee, WI 53233. Letters may be edited for length and clarity. ☐

Viewpoint

WE NEED NUCLEAR POWER IN SPACE

by John R. Casani

Deputy assistant laboratory director in the Office of Flight Projects at the Jet Propulsion Laboratory, Pasadena, California

Whether traveling to the surface of Mars or past the giant outer planets, the spacecraft that have accomplished our most impressive missions in solar system exploration share one common characteristic: Each carried one or more industrial-looking, black, flanged cylinders about the size of a household wastebasket.

These unadorned canisters are radioisotope thermoelectric generators, or RTGs, the devices that provide electrical power to spacecraft traversing the cold and dark reaches of the solar system. RTGs are as uncomplicated and reliable as they are unsung. Without them, most of the solar system would be inaccessible.

The storms of Jupiter and Saturn's elaborate rings would not have been seen without it.

Despite a long history of safe applications in space exploration, RTGs are occasionally included in broad expressions of public concern about space nuclear power. These concerns, however, are directed primarily at Earth-orbiting nuclear reactors used by the Soviet Union and proposed for U.S. military and civilian applications.

This concern about the use of nuclear power in space comes largely from two sources. NASA astrophysicists have found that gamma-ray detectors on orbiting observatories are frequently blinded by the gamma-ray emissions from Earth-orbiting reactors. Another group comprised of various scientists, legislators, and citizens' groups objects to the use of nuclear reactors in Earth orbit for philosophical or safety reasons.

Neither of these groups, however, have questioned the rationale for or the benefits of RTGs used in solar system exploration. Proposed Congressional legislation calling for a ban on Earth-orbiting reactors specifically exempts RTGs and nuclear reactors used for deep-space exploration. And in a recent statement calling for a worldwide ban on Earth-orbiting reactors, the American Federation of Scientists acknowledged the necessity and validity of using RTGs for deep-space missions.

Simply put, the choice facing NASA or any other space agency is clear: Either use a nuclear power source or forget about sending spacecraft to the outer planets, comets, and asteroids, and forget about ever landing anything on Mars.

RTGs have been used on NASA spacecraft for more than two decades without failure or incident involving radioactive hazard. They are simple, compact, highly reliable, and impervious to the high-radiation environments of deep space. And they are built tough enough to survive postulated accidents.

RTGs are used where, because of distance or spacecraft operational life requirements, no other power system will work. Solar panels can be used nearly everywhere inside the orbit of Mars, but beyond that there is not enough sunlight to power them. Nor do any batteries exist that are capable of storing enough energy to power a spacecraft over the long voyage to the outer planets.

RTGs are also required on lunar and planetary landers. The nuclear power systems sustain landers and their electric heaters through cold nights on the Moon and Mars. Even though there's enough sunlight on Mars for solar panels to work, dust storms on the surface would soon destroy them.

Were it not for RTGs, we would not have seen, through *Voyager*'s eyes, the fantastic storms of Jupiter. The elaborate rings of Saturn would still appear to us as three intriguing but monolithic bands. Io's erupting volcanoes would remain undiscovered. And we would still lack any direct evidence relevant to the question of whether life ever existed on Mars.

Many upcoming missions also rely on RTGs. The *Galileo* mission to Jupiter will be launched in October, and the joint NASA-European Space Agency *Ulysses* mission over the poles of the Sun is scheduled for 1990. NASA's planned *Comet Rendezvous Asteroid Flyby* mission and the *Cassini* spacecraft to Saturn and its moon Titan will also use RTGs.

We in the business of planetary exploration are grateful for the thoughtful recognition by policy makers and the public of the need to use nuclear power to fulfill NASA's charter to explore the solar system. While RTGs by their nature are not without risk, they are indispensable to our missions. The task ahead is to ensure that RTGs continue to be safely managed and flown. ☐

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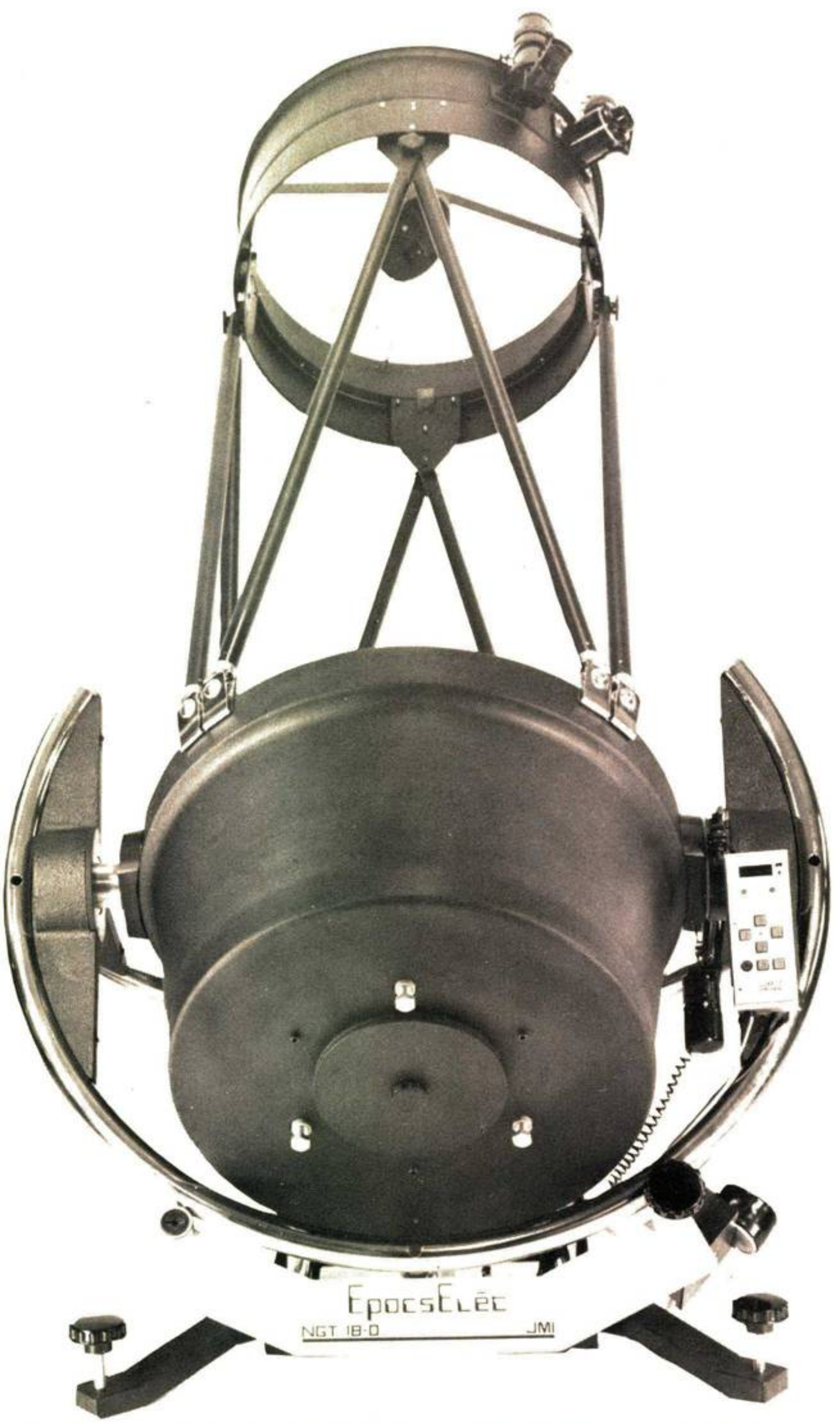

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WIDTH: 36'' **DEPTH:** 30''
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VOYAGER 2 *REVEALS NEPTUNE'S BELTS, CLOUDS*

Photographs taken by cameras aboard the *Voyager 2* spacecraft suggest that far more detail will be visible on Neptune than was seen in the atmosphere of Uranus.

The images, which were taken in January when the spacecraft was 195 million miles (310 million kilometers) from Neptune, reveal that Neptune has at least one large, bright cloud feature at 30° south latitude and a dark band circling a bright south polar region. These features stand out about as clearly as cloud bands on Saturn and ten times more clearly than cloud features on Uranus.

"We expected Neptune to be very active because it has a strong internal heat source," said planetary scientist Kevin Baines of the Jet Propulsion Laboratory. "Uranus doesn't have an internal heat source. It's a dead planet in comparison to Neptune."

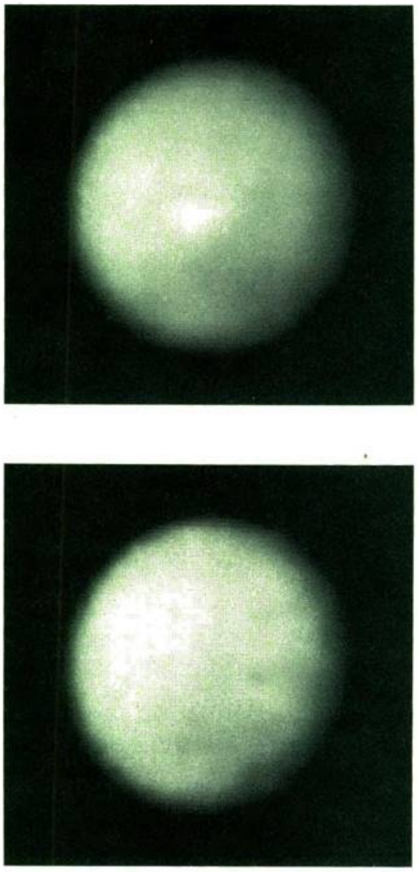
The photographs are sharp enough to show detail as small as 3,800 miles (6,000 kilometers) across, which is slightly better than the resolution of the best pictures taken from Earth. Neptune is 30,900 miles (49,500 kilometers) in diameter.

Astronomer Heidi Hammel of JPL said, "The bright cloud looks like the cloud feature we were tracking in June and July of 1988." Hammel used the 2.3-meter University of Hawaii telescope on Mauna Kea with narrow-band filters to enhance cloud structure. "What's great about these *Voyager* pictures is that they're taken with broad-band filters. That means as *Voyager* gets closer, we're going to see more cloud structure."

The motion of the bright cloud feature is consistent with Neptune's 17- to 18-hour rotation period derived from Earth-based imaging through large telescopes. "The rotation period varies with the latitude," said Hammel. "The 1988 bright cloud had a rotation period of 17.7 hours." Clouds Hammel observed in 1986 and 1987 at 38° south had a period of 17.0 hours.

Baines said that the escape of internal heat may drive ice and hydrocarbon aerosols high into Neptune's atmosphere, like a gigantic, terrestrial thunderstorm. "We're much further along in modeling Neptune's atmosphere than we were with Uranus before the flyby. It would be exciting to see one of these updrafts punching into the stratosphere."

Voyager will fly past Neptune on August 25 at 4 hours universal time (UT), passing only 3,000 miles (4,800 kilometers) above the cloud tops at closest approach. The spacecraft will observe Neptune and its ring arcs; search for new satellites; and observe Triton and Nereid, Neptune's two known satellites.



A BRIGHT CLOUD ON NEPTUNE rotates around the planet in a 17- to 18-hour period. *Voyager*'s cameras also show a dark band of clouds near the bright southern pole.

COMET HALLEY'S ACTIVE POLAR REGIONS

Pictures taken in 1986 by the *Giotto* spacecraft as it flew past the nucleus of Comet Halley showed several bright areas that were actively emitting gas. These areas were places where the dark material mantling the nucleus was thin or disturbed. The largest and brightest area lay at the north pole of the nucleus. Three astronomers now believe this region, together with a counterpart at the south pole, ejected about a third of all the dust that flowed into the coma and escaped.

Writing in *Science* (January 13, 1989), Harold J. Reitsema and W. A. Delamere of Ball Aerospace Corp. and Fred L. Whipple of the Smithsonian Astrophysical Observatory noted that Halley's nucleus has a 25° axial tilt and therefore has seasons. During the comet's long journey in toward perihelion, the Sun never sets as seen from the comet's south pole; the equinox came around the time of perihelion and thereafter the Sun rose for the north pole and stayed in its sky during the rest of the encounter.

These "arctic summers" sent waves of solar heat deep into the nucleus, where they caused outgassing that stripped off much of the mantle in the area around the comet's poles. This process is self-reinforcing — outgassing strips away mantle and exposes new volatiles to be outgassed. Therefore the reaction slowed and ceased only when the Sun dropped below the horizon as seen from the active region or when the comet moved far enough away from the Sun.

PHOBOS 1 *IMAGES THE SUN*

The first observations of the Sun taken from deep space were made by the Soviet Union's *Phobos 1* spacecraft last August when it was about 6 million miles from Earth on its way to Mars.

The images, taken shortly before an error by ground controllers broke contact with the probe, provide the first look at the Sun from a location other than Earth and also tie into results gathered during last September's International Solar Month (see "The Many Faces of the Sun" by Gerrit L. Verschuur, March 1989).

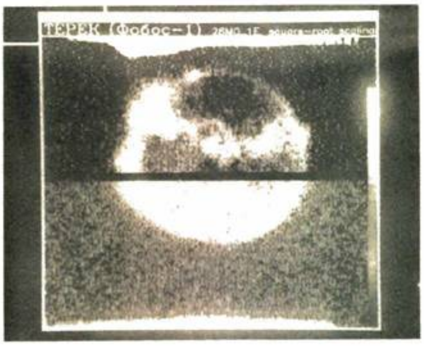
Igor Zhitnik and Aleksandr Urnov, two *Phobos* project scientists, have reported that TEREK, a joint Czechoslovak-Soviet instrument designed to image the Sun at x-ray wavelengths, worked successfully before contact was lost.

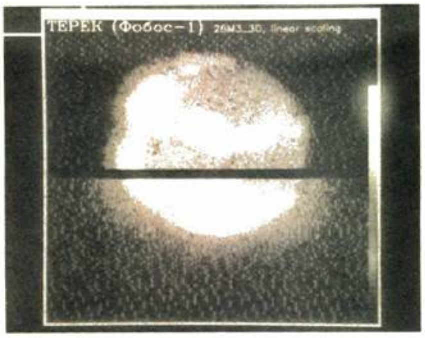
"It was because of the planned collaboration with other astronomers during International Solar Month in September that we got any data at all," Urnov said. Originally, plans called for TEREK to begin solar observations last October, but in preparation for the International Solar Month tests of the instrument were rescheduled for July and August. Contact was lost on September 1, but by then TEREK had taken several images.

The 175-angstrom image, taken at a soft x-ray wavelength, was made on August 26, 1988, and depicts gas in the quiet part of the Sun's corona with a temperature of 1.2 million kelvins.

Brighter spots indicate clouds of denser gas over actively erupting regions. The 304-angstrom image, taken at the same time as the other image, maps extreme ultraviolet radiation from gas with temperatures ranging from 30,000 K to 100,000 K. This radiation occurs in the lowest part of the corona or the upper chromosphere.

The dark region near the north pole (upper edge) in both images is a coronal hole, where the solar wind streams away into space along the Sun's magnetic field lines. Along the equator is a dark band, which astronomers did not expect to see and for which they as yet have no explanation. — *Gerrit Verschuur*





IMAGED BY *PHOBOS 1* on its way to Mars, the Sun shows coronal gas at soft x-ray wavelengths (top) and extreme ultraviolet (above).

NEW 3.5-METER TELESCOPE PLANNED FOR KITT PEAK

Kitt Peak, Arizona, may have another large telescope as early as 1992, the National Optical Astronomy Observatories (NOAO) has announced. The new 3.5-meter instrument, known as the WIN telescope, will be operated by the University of Wisconsin and Indiana University in coordination with the NOAO. It will be the second largest telescope on Kitt Peak and the fourth largest in the continental United States.

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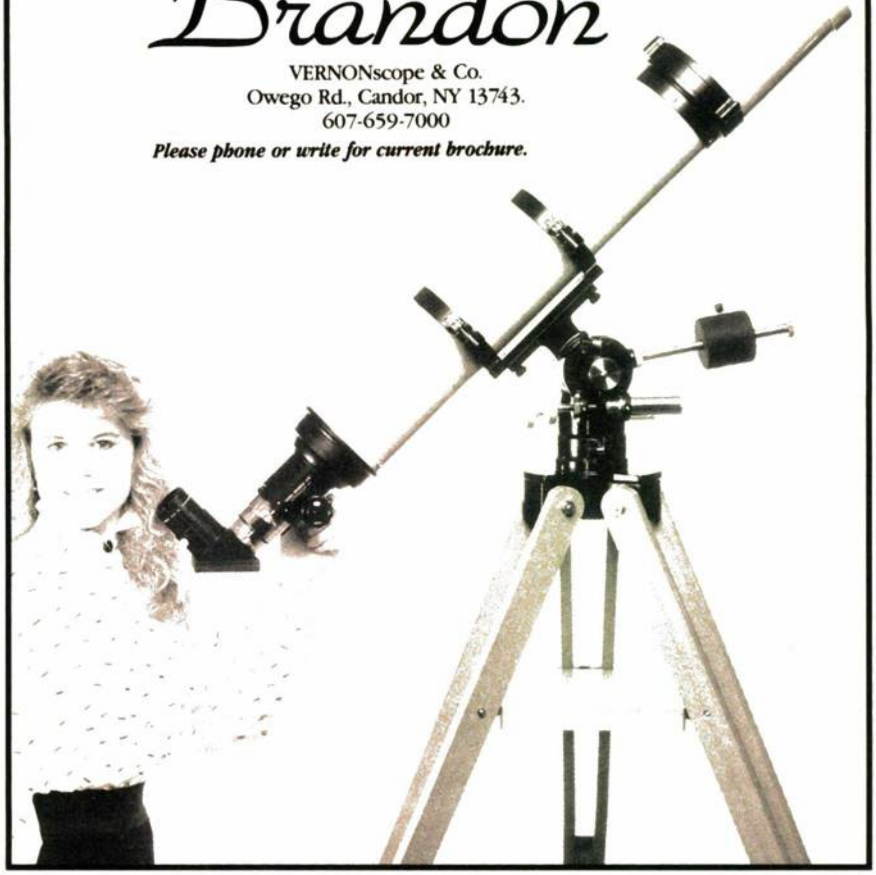

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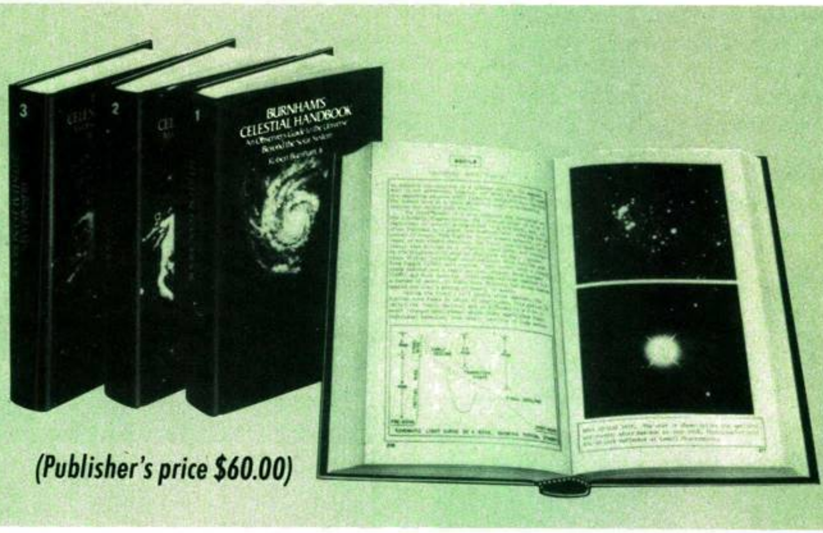
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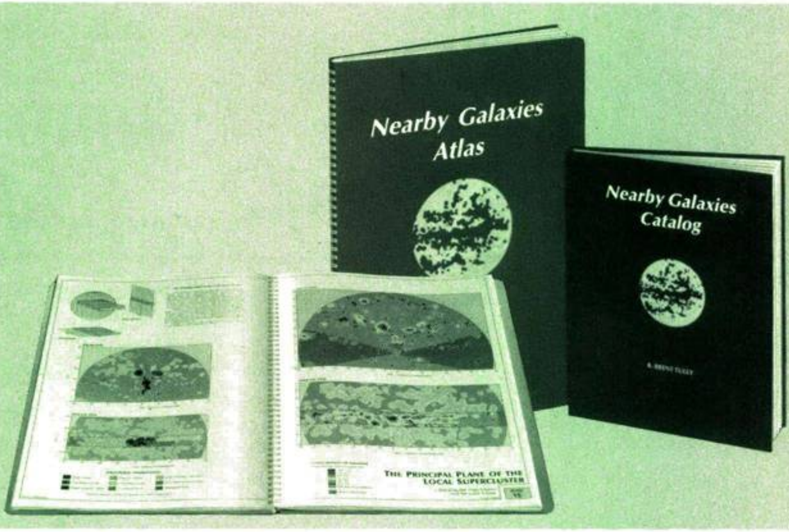
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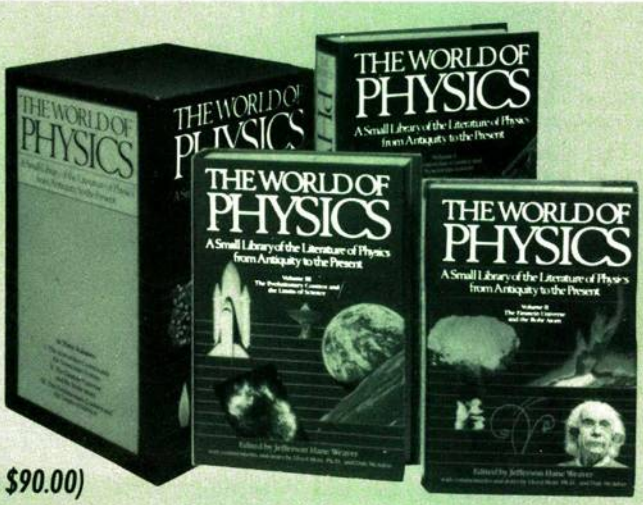
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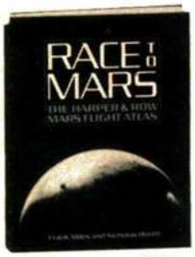
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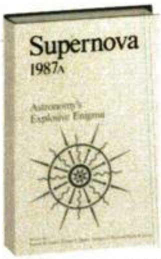
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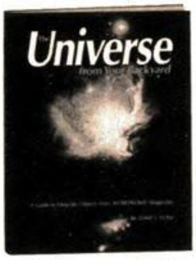
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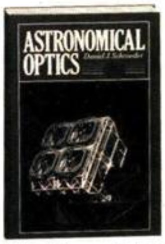
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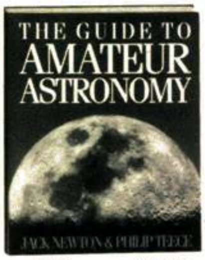
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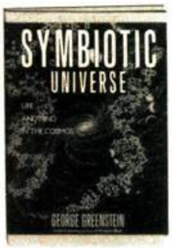
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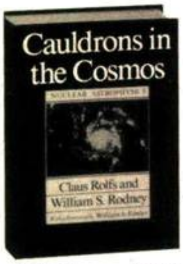
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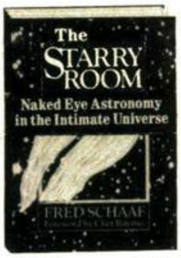
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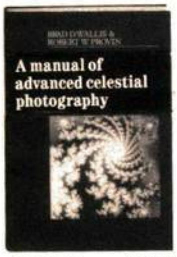
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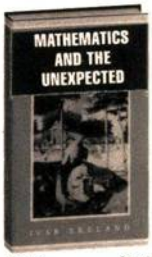
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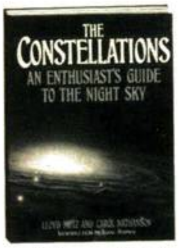
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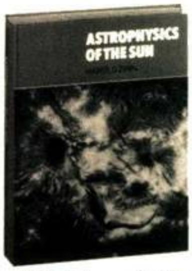
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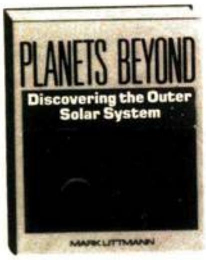
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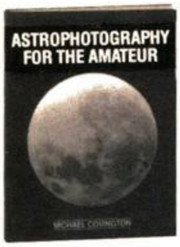
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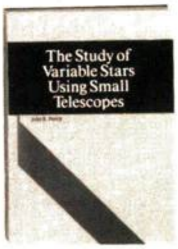
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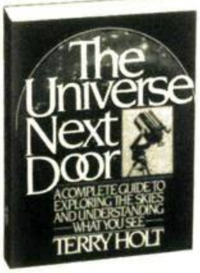
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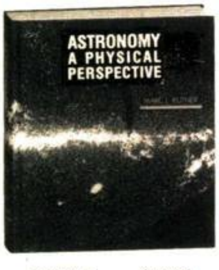
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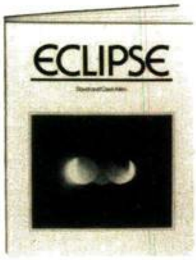

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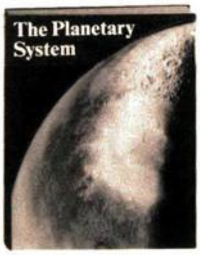
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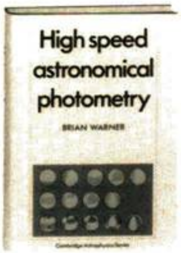
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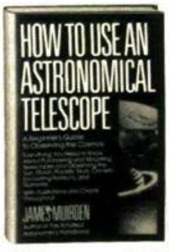
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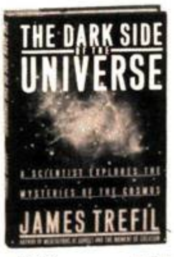
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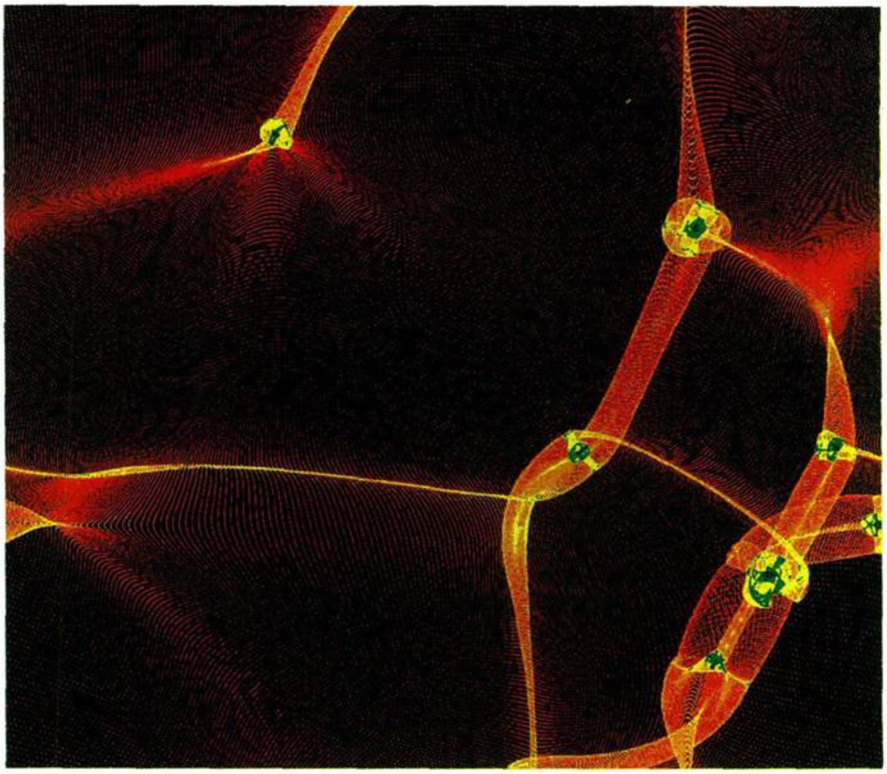
© 1989 Macmillan Book Clubs Inc. Astronomy 6/89 telescope intended primarily for spectroscopy of distant clusters of galaxies, star clusters, and galactic nebulae. Several dozen thin glass fibers will carry light from different objects to a spectrograph. This technique, called multiple-object spectroscopy, is extremely efficient because the spectra are taken simultaneously. The WIN telescope will thus free time on general-purpose telescopes in the 4-meter size range.

The new telescope will cost about $10 million and will be funded by the universities. NOAO will support the long-term operation of the facility. The construction schedule for the telescope depends on the rate at which funding can be obtained, but the telescope could be in operation as early as 1992.

The crucial first step in construction — casting the primary mirrror — is already completed. The University of Arizona Mirror Laboratory cast the 3.5-meter glass blank for the primary mirror in December 1988 using spin-casting technology (see Astronews, October 1988). It is the second large spin-cast mirror made at the laboratory.



BRIDGES OF MATTER link galaxy clumps even after the galaxies have collapsed. The results of this computer simulation may explain how supercluster chains form.

SUPERSTRUCTURES BETWEEN SUPERCLUSTERS

A new high-resolution computer model that simulates the clumping and stringing together of primordial matter in the early universe shows filaments still connected to galaxy superclusters long after those superclusters have collapsed. The model simulates various stages in the formation of superclusters of galaxies using "density perturbations," large-scale disturbances in the mostly smooth distribution of matter in the early universe.

Many cosmologists believe such density perturbations rippled through the universe like waves, causing matter to collect and eventually collapse into galaxies. The cause of density perturbations and how structures like galaxy clusters subsequently formed from them are two of the central issues being addressed by "computerized cosmology."

The numerical model, developed by Adrian L. Melott of the University of Kansas and Sergei F. Shandarin, a visiting Soviet astronomer at the University of Kansas, was run on a Cyber 205 supercomputer at the John von Neumann National Supercomputer Center, in Princeton, New Jersey. Melott and Shandarin's two-dimensional model employs 262,144 particles. This particle population gives a clear picture of the mass distribution over vast distances.

The model reveals structures that are difficult, if not impossible, to see in lower-resolution models. For example, the model shows clusters organized into elongated, sandwichlike structures similar to those observed in the Local Supercluster. Later stages of the simulation reveal "bridges" still linking clumps of matter even after gravity has gathered the small clumps into big ones. Melott and Shandarin believe these embedded structures may explain how "supercluster complexes" — great chains of superclusters on the order of one trillion light-years in length — remain intact over great distances for billions of years.

CALCIUM CARBONATE FOUND IN 'MARS' METEORITES

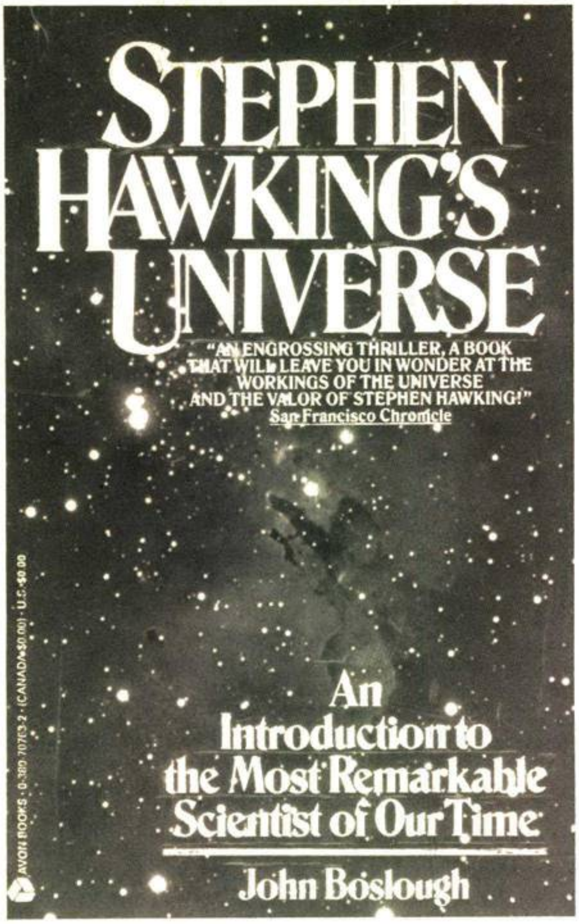
Two meteorites that possibly came from Mars have been found to contain calcium carbonate, on Earth the common sedimentary mineral that comprises limestone. If these meteorites are indeed from Mars, then this discovery offers the first direct evidence for carbonate rocks on that planet, reported James L. Gooding of NASA's Johnson Space Center in Houston, Texas. Finding carbonates on Mars is important because these minerals can be laid down only in a wet environment.

The two meteorites, one named Nakhla (after the location in Egypt where it fell) and the other Elephant Moraine 79001 (in Antarctica), belong to the so-called SNC group of meteorites. SNC, pronounced "snick," stand for Shergotty-Nakhla-Chassigny, a group of meteorites made from igneous rocks all about 1.3 billion years old. In addition, the shergottites (to which Elephant Moraine belongs) have been strongly shocked, probably by impact, and contain trapped gases with a chemical content that closely matches the Martian atmosphere sampled by *Viking*.

The calcium carbonate turned up in microscopic cavities in the two meteorites. From the mineral's placement in the rocks and from its isotopic composition, which differs from that of the calcium carbonate found on Earth, Gooding believes the mineral was emplaced in the rocks before they arrived here and is not a terrestrial contaminant.

In the case of Nakhla, the mineral occurs in veins that permeate the rock, which indicates that it formed in the same voids where it is now found. The calcium carbonate in Elephant Moraine, on the other hand, shows signs of wear, which suggests that it formed elsewhere, may have blown around as dust for a while, and then was forcibly "married" to the rock, perhaps at the time when the meteorite was severely shocked 180 million years ago.

The role played by water in Mars' past has long been a thorny question for planetary scientists. Gooding's findings indicate that a watery geochemistry was active on Mars as recently as 1.3 billion years ago, much more recently than many scientists had suspected.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Space News

PROBING THE MARS QUESTION

In the view of some space advocates, a manned journey to Mars is inevitable: we know how to do it and in all likelihood we will do it soon. But a recent conference on Mars exploration sponsored by the Space Policy and Law Center at the University of Central Florida made it clear that not everyone in the space community shares this optimistic view or the same assumptions about what a Mars mission would be.

Apollo astronaut John Young predicted that a manned trip to Mars would take place within the next fifty years, but he noted that a similar prediction he made twenty years ago — the establishment of a lunar base — had not yet come about. "In 1969 I believed that the only things that would prevent a U. S. base on the Moon after twenty years would be a national disaster or World War III," Young said. What is needed, according to Young, is "the national will" to do it.

Young suggested that a joint U.S./Soviet mission may not be the best way to generate support for a trip to Mars. "National competition is healthy when you really want to get things done," he said.

Another missing ingredient in any manned Mars scenario, according to Wendell Mendell, chief scientist of the lunar base studies office at NASA's Johnson Space Center, is a big rocket to get a Mars craft into orbit. The Soviets now have this capability with their Energia rocket. "This shows that there are other countries with the interest, abilities, and technological skills to open up the solar system. These skills are not ours alone," Mendell said.

From the perspective of planetary science, Eugene Levy of the University of Arizona warned against concentrating on the exploration of Mars at the expense of the other terrestrial planets. In order to better understand the solar system, scientists need to study Venus, Earth, and Mars together. "The three terrestrial planets are each different experiments with different results," Levy said.

A recurring theme was the condition of the U.S. space program. In Levy's view, "There has been little progress toward a functional program."

The conference, held in February, was the University's fourth annual Space Policy Symposium. — *David S. F. Portree*

WILL ASTRONAUTS EXPLORE Mars or its moon, Phobos, one day? A recent conference on Mars exploration generated several different answers to that question.

SOVIET PHOBOS 2 *MISSION FAILS*

On March 27, two weeks before a dramatic low-altitude pass across the surface of Mars' moon Phobos, the unmanned Soviet spaceprobe *Phobos 2* lost radio contact with Earth. At press time, ground controllers believed that contact was unrecoverable and deemed the mission lost. The radio problem arose when the craft could not regain "stable contact" as it turned its antenna back toward Earth after a data-collection run.

Although *Phobos 2* had taken photographs of Mars and Phobos and collected other data about chemical abundances on the Martian surface, the main part of the mission was a low altitude (150-foot) cruise over the surface of the moon. During this pass, a fixed-site lander probe and a mobile "hopper" probe were to have analyzed the soil of Phobos directly.

Phobos 2 was the remaining spacecraft of a pair launched toward Mars a year ago. Last August, an erroneous command radioed to *Phobos 1* caused that craft to point its antenna away from Earth and lose radio contact. Unable to receive further commands, *Phobos 1* sailed past Mars this January without firing its braking rocket. *Phobos 2* arrived in late January and was in a circular orbit around Mars when contact was broken.

It was unclear whether human error led to the problem with *Phobos 2,* but the spacecraft had also been experiencing hardware problems. It was communicating on its backup radio transmitter, and the television camera and other electrical subsystems were not functioning as planned.

SPACE UNIVERSITY'S SUMMER SESSION MOVES TO FRANCE

The International Space University will take its second step toward its goal of becoming a worldwide center for space education when it convenes its second summer session in France this month. Last year the ISU, a nonprofit organization based in Boston, held its first eight-week summer session at the Massachusetts Institute of Technology.

The ISU's graduate-level program is expected to draw 120 students this year from over twenty-five countries to study with an international faculty. The 1988 summer session was attended by 104 students. The ISU plans to offer summer sessions each year until 1992 when a permanent campus is created and the ISU will begin to grant graduate degrees.

According to Reimar Luest, director general of the European Space Agency, holding the session at the Universite Louis Pasteur in Strasbourg indicates that the fledgling ISU is serious about its international character. "The decision to come to Europe will make it a truly international endeavor," said Luest.

SPACE TELESCOPE *TO 'FLY' IN AUGUST*

Although the *Hubble Space Telescope* is not scheduled to be launched into orbit until December, the long-awaited mission will finally "get off the ground" this summer. NASA has decided to ship the telescope to Kennedy Space Center by air instead of by boat to save time and reduce security risks.

The *Space Telescope* is scheduled to leave the Lockheed Missiles and Space Company plant in Sunnyvale, California, where it is undergoing final assembly and testing, some time in August. An Air Force C-5A Galaxy transport aircraft will carry it to Florida.

The space shuttle *Discovery* is scheduled to carry the *Space Telescope* on the last leg of its journey into orbit on December 11.

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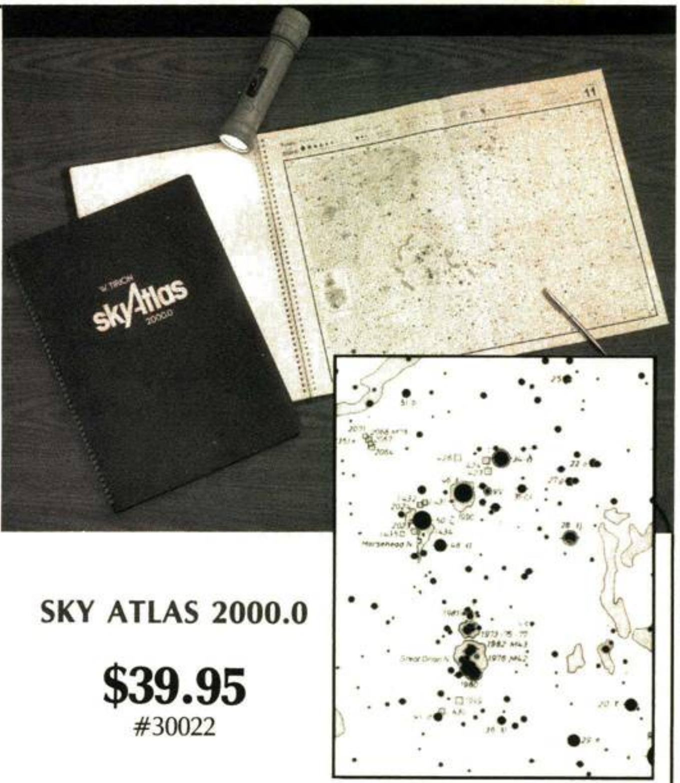

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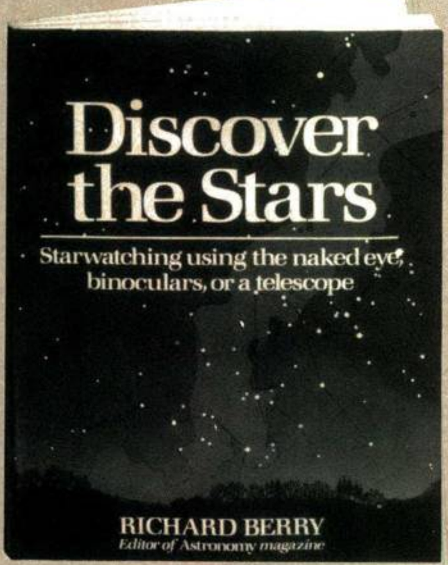
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Amateur News

CANADIANS VISIT THE SOVIET UNION

A group of amateur astronomers from the Astronomical Society of Montreal recently had the opportunity to visit major astronomical sites in the Soviet Union. Marc A. Gelinas and Raymond Auclair, members of the society and of the Royal Astronomical Society of Canada, reported that after several members expressed a strong interest in going, the club's board voted to sponsor a trip to the U.S.S.R.

Once in the Soviet Union, the Canadians saw a wide range of astronomical sites. "Near the village of Zelenchukskaya in the Caucasus Mountains," explained Gelinas, "we saw RATAN 600, the world's largest single dish radio telescope. As we approached the instrument, we were surprised to see the 600-meter 'dish' buried in the ground face-up, so only the rim sticks out of the ground. The rim, which collects energy from stars and galaxies, is made of nine hundred flat, rectangular mirrors that focus on a central collector."

A thirty-minute drive brought the Canadians to another astronomical attraction. "We were stunned to see the 50-meter dome of the 6-meter telescope," said Gelinas. "The dome is dwarfed by a giant crane used to lift the mirror. The 6-meter instrument is currently the largest optical telescope in the world. However, according to our host, Yuri Balega, only about 170 nights per year are good for observing and then the seeing averages only 1 arcsecond. Except for cows munching on sparse patches of grass about the observatory, the building and grounds appear like those of a Western institution."

Gelinas and friends found one of the finest astronomical communities to be the Crimean Astrophysical Observatory. "From Yalta," Gelinas continued, "we travelled to the Crimean Observatory, site of ten telescopes. We were greeted by Professor Nikolai Chernykh, who showed us the Crimean site under a warm Sun. Astronomer Ludmilla Kartachova showed us the Sun in Hα with the Lyot coronagraph and told us about her difficulties in getting Kodak films. At the 1.3-meter Cassegrain telescope, Nellie Merkalova described how she studies Seyfert galaxies with a Finnish-built polarimeter. We also saw the Crimean site where cosmonauts are trained to use telescopes in preparation for stays on the space station *Mir.*"

The Canadians also visited the Ukrainian Astrophysical Observatory and Pulkovo Observatory. "After spending two weeks in the Soviet Union, I came to greatly appreciate the astronomy they do under relatively difficult conditions," related Gelinas. "They have frequent poor seeing, troubles with equipment and supplies, and a personnel shortage. Despite this, Soviet astronomers have contributed some of the most important research to date."

PUBLIC OBSERVATORY OPENS IN NEW MEXICO

Last year John Gilkison purchased eight-and-a-half acres, twenty-five miles northwest of Las Cruces, New Mexico, constructed a domed observatory with a 10-inch telescope, and opened his own public observatory. The facility can be used by anyone who reserves it in advance and pays a small use fee.

Gilkison is someone who savors studying the sky and sharing his enthusiasm with others. He began crusading for a National Public Observatory several years ago and in 1986 attempted to interest the New Mexico State Park System in the idea. However, the state balked, leaving Gilkison on his own.

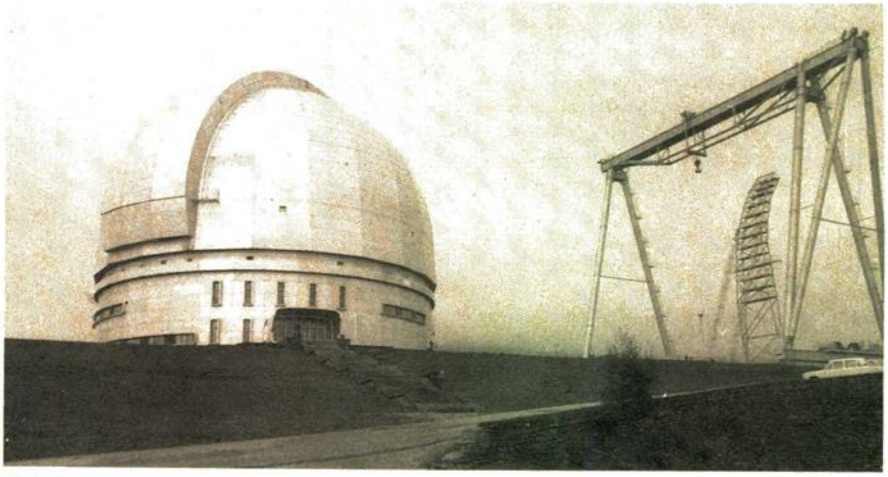
The Public Astronomical Observatory is now open to student groups, scout groups, teachers, and the general public. It is essentially a nonprofit undertaking: Gilkison charges a $5 advance reservation fee and $2 per person per night. For daytime solar observing he charges $1 per person per day. For more information on the Public Astronomical Observatory, contact Gilkison at P.O. Box 56, Radium Springs, NM 88054.

ASTRO-FEST II DRAWS ENTHUSIASTIC CROWD

Over 1,300 amateur astronomers gathered in Farmington, Connecticut, on March 18 for the second New England Astro-Fest, an annual astronomy retail show. Twenty-three exhibitors displaved and sold items such as telescopes, eyepieces, filters, cameras, books, magazines, atlases, videotapes, and even meteorites. The one-day event gave amateurs the chance to talk with manufacturers and examine new products before buying.

"There's nothing else like it on the East Coast," said Bob Rinaldi, organizer of the event and owner of New England Astro-Optics. "Stellafane prohibits commercial advertising, so we wanted to create a place where amateurs could keep in touch with what's going on with astronomy products." West Coast and Southern conventions, such as Riverside and the Texas Star Party, permit commercial displays.

When they weren't examining the goods, Astro-Fest participants listened to lectures given by a variety of speakers, including Al Nagler, Roger Tuthill, and David Eicher The event closed with a banquet and a talk on the *Hubble Space Telescope* given by Peter Silverglate of the Perkin-Elmer Corporation.



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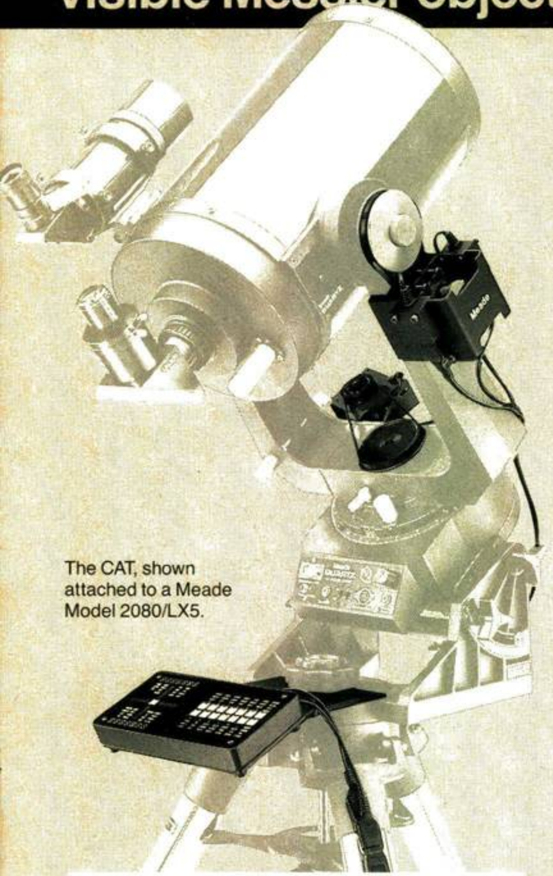
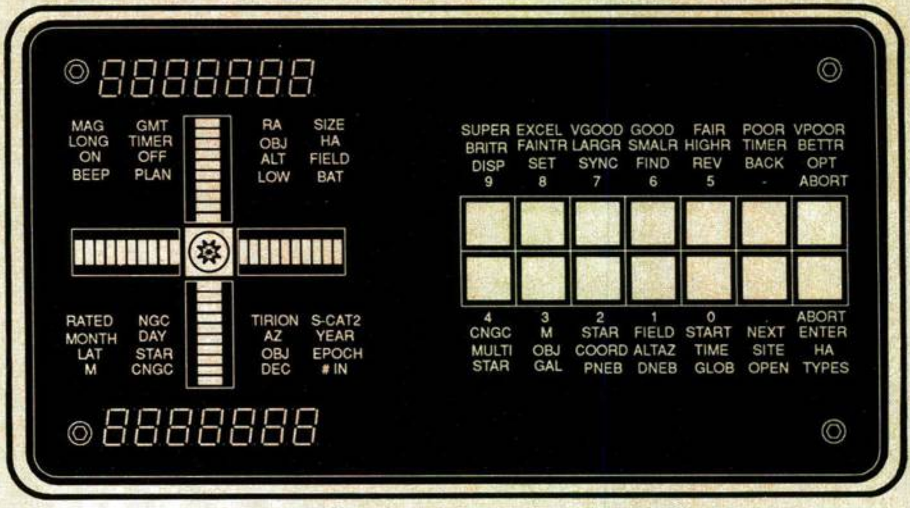


The CAT, shown attached to a Meade Model 2080/LX5.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How it works: Included with the CAT are 2 precision optical encoders that mount on the telescope and sense the telescope's position in RA and Dec. Using the CAT's large, red-illuminated crossline display, the observer manually moves the telescope to the position dictated by the crosslines. The CAT unerringly positions the desired object precisely in the center of the telescopic field. In addition, digital readouts on the display console continuously display R.A. and Declination.

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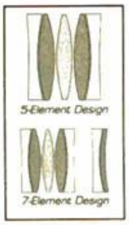

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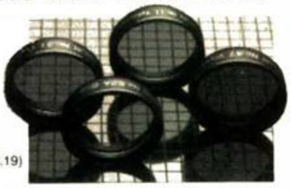

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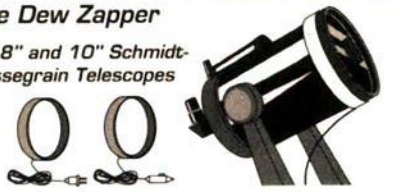

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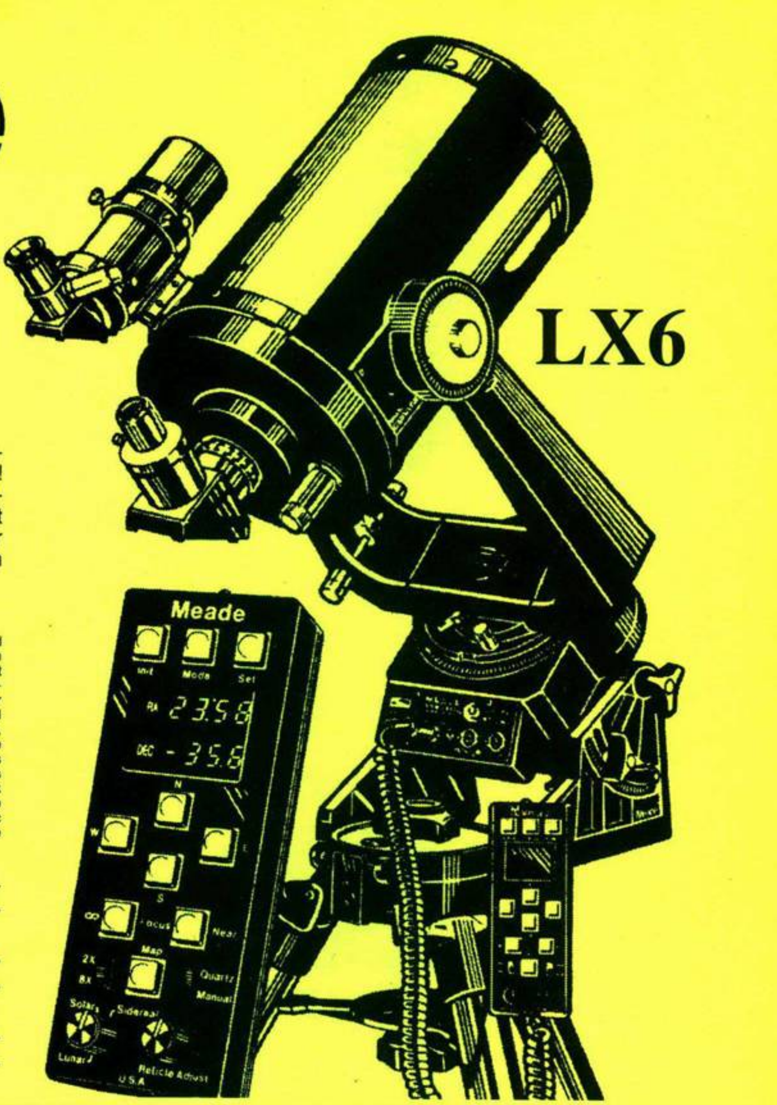


Meade's new LX6's boast an *f*/6.3 optical system which permits astrographic exposures in only four-tenths of the time required by an *f*/10 system! In addition, they come complete with quartz-locked, micro-computer-controlled, electronic pulse-motor drive, sophisticated hand control unit with astrographic drive correction functions built-in, 2.00" star diagonal for advanced, premium-grade eyepieces, giant 9x60mm finderscope, built-in provision for optional digital readouts or CAT system, and much more!

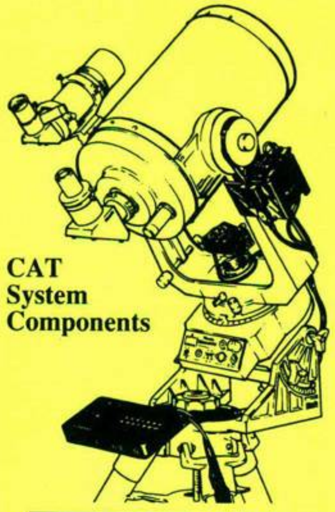
STANDARD FEATURES & FACTORY-SPECIFIED EQUIP:

Complete *f*/6.3 telescope tube assembly (8" or 10" aperture, 1,280mm or 1,600mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity mirrors; ultra-smooth anti-backlash focus mechanism; giant 9x60mm illuminated-reticle polar-alignment viewfinder with quick-disconnect mounting bracket; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000 26mm Super Plossl eyepiece, 1.25" (49x or 62x); rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; digital quartz-locked, micro-computer-controlled, electronic sidereal-rate pulse-motor drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Center hand-control unit (note: Meade's Digital Readout System is an ***optional*** accessory); 115Vac/60Hz power adapter with 25 ft. cord; DC battery-pack *(batteries not included)* with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth, latitude scale, bubble level and magnetic compass; ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; instruction manual; limited lifetime warranty.

2080 LX6	(List: $ 4,400)	CALL
2120 LX6	(List: $ 6,400)	CALL
Optional Digital Readout System:		
Mod. 9068, *for* 2080 LX6	(List: $ 590)	CALL
Mod. 9070, *for* 2120 LX6	(List: $ 590)	CALL
Package: Telescope *and* Optional Digital Readout System, together:		
2080 LX6 *with* Mod. 9068	(List: $4,990)	CALL
2120 LX6 *with* Mod. 9070	(List: $6,990)	CALL

FREE FREIGHT! (UPS Ground) for the LX6's shown above

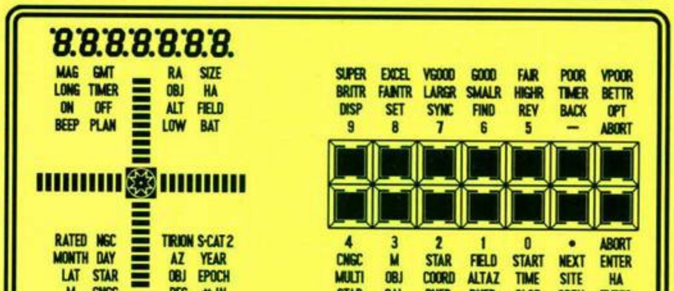
Meade's Computer-Aided Telescope System


CAT
System
Components

Meade's Computer-Aided Telescope (the "CAT") system has most of the advantages of a computer-controlled telescope at only a fraction of the cost. Consisting of a specially-designed, high-speed, extremely powerful computer, along with a pair of high-resolution incremental shaft encoders and their associated mounting hardware, drive components and cabling (*see general arrangement drawing at left, and panel layout drawing at right*), the CAT can readily and quickly direct you to any of the thousands of celestial objects whose coordinates and other descriptive information are permanently stored in its 1Mb plug-in EPROM database, ***including all of the planets***, as well as to any other celestial object of known coordinates (comets, asteroids, quasars, super-novae, etc.). The computer is loaded with extra features and functionality as the panel legends, at right, indicate.

For the computer-literate, there is also a version of the CAT available with an RS-232C port (the "CAT-COM") for connection to a "PC" compatible personal computer. CAT-COM includes four "demonstration" software subroutines, written in BASIC, to show you how to address and control the CAT from your own computer, as well as the necessary RS-232C interconnect cable. The software is supplied on a 5.25" 360Kby diskette, with backup source-code listings in the instruction manual.

The CAT is available for most fork-mounted Schmidt-Cassegrain telescopes, but has been ***electronically integrated*** with the new LX6 series, so that the encoders and the CAT computer plug directly into the drive-base. Consequently, during our introduction of the LX6 series telescopes, we are offering extra savings on packages consisting of an LX6 telescope and one or the other of the CAT systems.



Optional Computer-Aided Telescope (CAT) System:		
CAT *for* 2080 *or* 2120 LX6	(List: $1,990)	CALL
CAT-COM *for* 2080 *or* 2120 LX6	(List: $2,290)	CALL
Package: Telescope *and* Optional CAT System, together:		
2080 LX6 *with* CAT	(List: $6,390)	CALL
2080 LX6 *with* CAT-COM	(List: $6,690)	CALL
2120 LX6 *with* CAT	(List: $8,390)	CALL
2120 LX6 *with* CAT-COM	(List: $8,690)	CALL
Hardcopy Listing of CAT Database	(List: $ 60)	CALL

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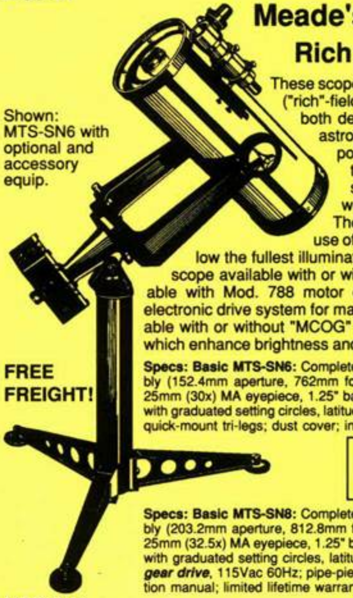


Shown: MTS-SN6 with optional and accessory equip.

FREE FREIGHT!

Meade's Schmidt-Newtonians

Rich, Fast and Photographic!

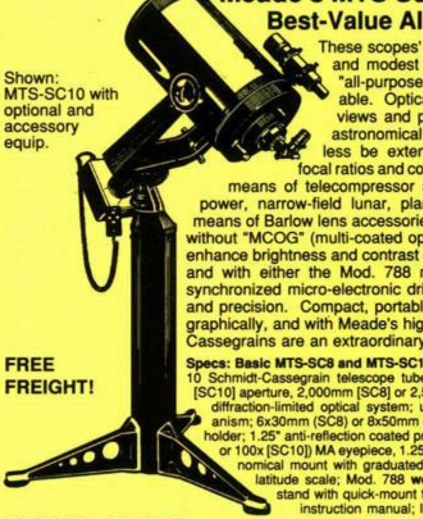
These scopes' wide, bright, highly corrected fields of view ("rich"-fields) and "fast" focal ratios make them ideal for both deep space visual observing and prime focus astrophotography. Easy and convenient to transport and use because of their "fork" -type equatorial mounts, they are excellent all-around scopes for those just starting in astronomy, as well as for experienced astrophotographers. Their 1.25"/2.00" focusers not only permit the use of the greatest variety of eyepieces, but also allow the fullest illumination of the film-plane during photography. 6" scope available with or without Mod. 788 motor drive. 8" scope available with Mod. 788 motor drive, or "LX3" quartz-synchronized micro-electronic drive system for maximum accuracy and precision. All are available with or without "MCOG" (multi-coated optics group) optical coatings, which enhance brightness and contrast of visual and photographic images.

Specs: Basic MTS-SN6: Complete 6"A, f/5 Schmidt-Newtonian telescope tube assembly (152.4mm aperture, 762mm focal length); 2" helicoid focuser, with 1.25" adapter; 25mm (30x) MA eyepiece, 1.25" barrel; rugged dual-fork equatorial astronomical mount with graduated setting circles, latitude adjustment, and latitude scale; pipe-pier stand with quick-mount tri-legs; dust cover; instruction manual; limited lifetime warranty.

Ask about our special finderscope & barlow Accessory Packages for these MTS Schmidt-Newtonians

Specs: Basic MTS-SN8: Complete 8"A, f/4 Schmidt-Newtonian telescope tube assembly (203.2mm aperture, 812.8mm focal length); 2" helicoid focuser, with 1.25" adapter; 25mm (32.5x) MA eyepiece, 1.25" barrel; rugged dual-fork equatorial astronomical mount with graduated setting circles, latitude adjustment, and latitude scale; Mod. 788 ***worm-gear drive***, 115Vac 60Hz; pipe-pier stand with quick-mount tri-legs; dust cover; instruction manual; limited lifetime warranty.

MTS-SN6	(List: $ 1,050)	CALL
MTS-SN6, MCOG	(List: $ 1,130)	CALL
MTS-SN6, 788 MtrDrv	(List: $ 1,200)	CALL
MTS-SN6, 788 MtrDrv, MCOG	(List: $ 1,280)	CALL
MTS-SN8, 788 MtrDrv	(List: $ 1,500)	CALL
MTS-SN8, 788 MtrDrv, MCOG	(List: $ 1,590)	CALL
MTS-SN8, LX3 MtrDrv	(List: $ 1,800)	CALL
MTS-SN8, LX3 MtrDrv, MCOG	(List: $ 1,890)	CALL



Shown: MTS-SC10 with optional and accessory equip.

FREE FREIGHT!

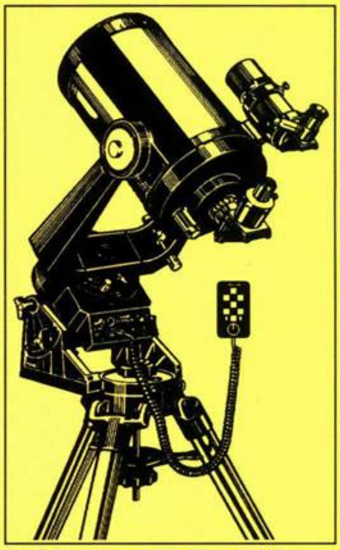
Meade's MTS Schmidt-Cassegrains

Best-Value All-Around Performers!

These scopes' "general-purpose" f/10 focal ratios and modest prices make them the best-value "all-purpose", "do-everything" scopes available. Optically capable of delivering exquisite views and photographs of almost all types of astronomical objects "as-is", they may nevertheless be extended to extremely "fast" effective focal ratios and correspondingly wide fields of view by means of telecompressor accessories, or to extremely high power, narrow-field lunar, planetary and multiple-star work by means of Barlow lens accessories. Each scope is available with or without "MCOG" (multi-coated optics group) optical coatings, which enhance brightness and contrast of visual and photographic images, and with either the Mod. 788 motor drive, or the "LX3" quartz-synchronized micro-electronic drive system for maximum accuracy and precision. Compact, portable, easy to use visually and photographically, and with Meade's high-quality optics, the MTS Schmidt-Cassegrains are an extraordinary value in astronomical telescopes.

Specs: Basic MTS-SC8 and MTS-SC10: Complete 8"A (SC8) or 10"A (SC10) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm [SC8] or 254mm [SC10] aperture, 2,000mm [SC8] or 2,500mm [SC10] focal length), with certified diffraction-limited optical system; ultra-smooth anti-backlash focus mechanism; 6x30mm (SC8) or 8x50mm (SC10) viewfinder; 1.25" visual accessory holder; 1.25" anti-reflection coated prism-type star diagonal; 25mm (80x [SC8] or 100x [SC10]) MA eyepiece, 1.25" barrel; rugged dual-fork equatorial astronomical mount with graduated setting circles, latitude adjustment; and latitude scale; Mod. 788 **worm-gear drive**, 115Vac 60Hz; pipe-pier stand with quick-mount tri-legs; dust covers for optical apertures; instruction manual; limited lifetime warranty.

MTS-SC8, 788 MtrDrv	(List: $ 1,800)	CALL
MTS-SC8, 788 MtrDrv, MCOG	(List: $ 1,890)	CALL
MTS-SC8, LX3 MtrDrv	(List: $ 2,150)	CALL
MTS-SC8, LX3 MtrDrv, MCOG	(List: $ 2,240)	CALL
MTS-SC10, 788 MtrDrv	(List: $ 2,780)	CALL
MTS-SC10, 788 MtrDrv, MCOG	(List: $ 2,950)	CALL
MTS-SC10, LX3 MtrDrv	(List: $ 3,180)	CALL
MTS-SC10, LX3 MtrDrv, MCOG	(List: $ 3,350)	CALL



Meade's LX5's

Fully equal to LX6's in terms of their standard equipment, they come complete with quartz-lock microelectronic pulse motor drive, sophisticated hand control unit with photographic drive correction functions built-in, 2.00" star diagonal for advanced, premium-grade eyepieces, & giant 9x60mm finderscope!

Specs: 2080/LX5 and 2120/LX5: Complete 8"A (2080/LX5) or 10"A (2120/LX5) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm or 254mm aperture, 2,000mm or 2,500mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity mirrors; ultra-smooth anti-backlash focus mechanism; giant 9x60mm illuminated-reticle polar-alignment viewfinder with quick-disconnect mounting bracket; 2.00" mirror-type star diagonal, with 1/10 wave multi-coated mirror and adapter for 1.25" eyepieces; Series 4000 26mm Super Plossl eyepiece, 1.25" (77x or 96x); rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; digital quartz micro-electronic sidereal-rate pulse-motor drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Center hand-control unit; 115Vac 60Hz AC power adapter with 25 ft. cord; DC battery-pack *(batteries not included)* with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level, magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; audio cassette instructions; instruction manual; limited lifetime warranty.

2080/LX5, MCOG, Wedge, Tripod (as above)	(List: $ 3,800)	CALL
2120/LX5, MCOG, Wedge, Tripod (as above)	(List: $ 5,400)	CALL

FREE FREIGHT! (UPS Ground) for the LX5's above

Meade's LX3's - Still Going STRONG!

Specs: 2080/LX3 and 2120/LX3: Complete 8"A (2080/LX3) or 10"A (2120/LX3) f/10 Schmidt-Cassegrain telescope tube assembly (203.2mm or 254mm aperture, 2,000mm or 2,500mm focal length), with certified diffraction-limited optical system; MCOG ("Multi-Coated Optics Group"), consisting of multi-layer anti-reflection coatings on corrector plate and enhanced reflectivity (multi-layer over-coated) mirrors; ultra-smooth anti-backlash focus mechanism; large 8x50mm viewfinder; 1.25" visual back (eyepiece holder); 1.25" prism-type star diagonal, anti-reflection coated; 25mm (80x or 100x) MA eyepiece, 1.25" barrel; rugged dual-fork astronomical mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; quartz micro-electronic sidereal-rate drive system and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxiliary electronic equipment; Electronic Command Center hand-control unit **(10" 2120/LX3 only)**; 115Vac 60Hz AC power adapter with 25 ft. cord; 25 ft. DC power cord w/cigarette-lighter plug; Deluxe Equatorial Wedge with micrometric adjusters for latitude and azimuth (polar-alignment adjustments), latitude scale, bubble level and magnetic compass (and no-tool knob set on 8" scope only); ultra-rigid adjustable-height Field Tripod; dust covers for optical apertures; foam-lined carrying case for scope-tube/fork-mount/drive-base assembly; instruction manual; limited lifetime warranty.

2080/LX3, MCOG, Wedge, Tripod (as above)	(List: $ 3,520)	CALL
2120/LX3, MCOG, Wedge, Tripod (as above)	(List: $ 5,200)	CALL

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Meade's Advanced Electronic Systems
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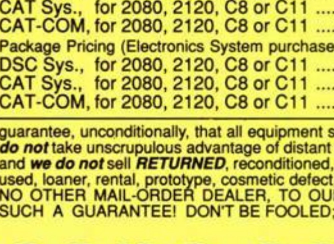

FREE FREIGHT!

Meade's "CAT" and "DSC" Systems enhance your ***observing*** pleasure by virtually eliminating the difficulties of "finding". Sophisticated micro-computer technology and software make it possible! The CAT System (at left), contains an internal catalog of over 7,500 astronomical objects. The DSC System provides precise, digital coordinate readout too, but without the internal catalog. Both systems are easy, bolt-on retrofits - no drilling or tapping required. A variant of the CAT ("CAT-COM") can communicate with a PC-type computer (see opposite page for details). Package pricing is available when either System is purchased at the same time as its telescope (not for MTS).

Individual System Pricing:

DSC Sys., for 2080, 2120, C8 or C11	(List: $ 700)	CALL
CAT Sys., for 2080, 2120, C8 or C11	(List: $ 1,990)	CALL
CAT-COM, for 2080, 2120, C8 or C11	(List: $ 2,290)	CALL

Package Pricing (Electronics System purchased at same time as its telescope):

DSC Sys., for 2080, 2120, C8 or C11	(List: $ 700)	CALL
CAT Sys., for 2080, 2120, C8 or C11	(List: $ 1,990)	CALL
CAT-COM, for 2080, 2120, C8 or C11	(List: $ 2,290)	CALL

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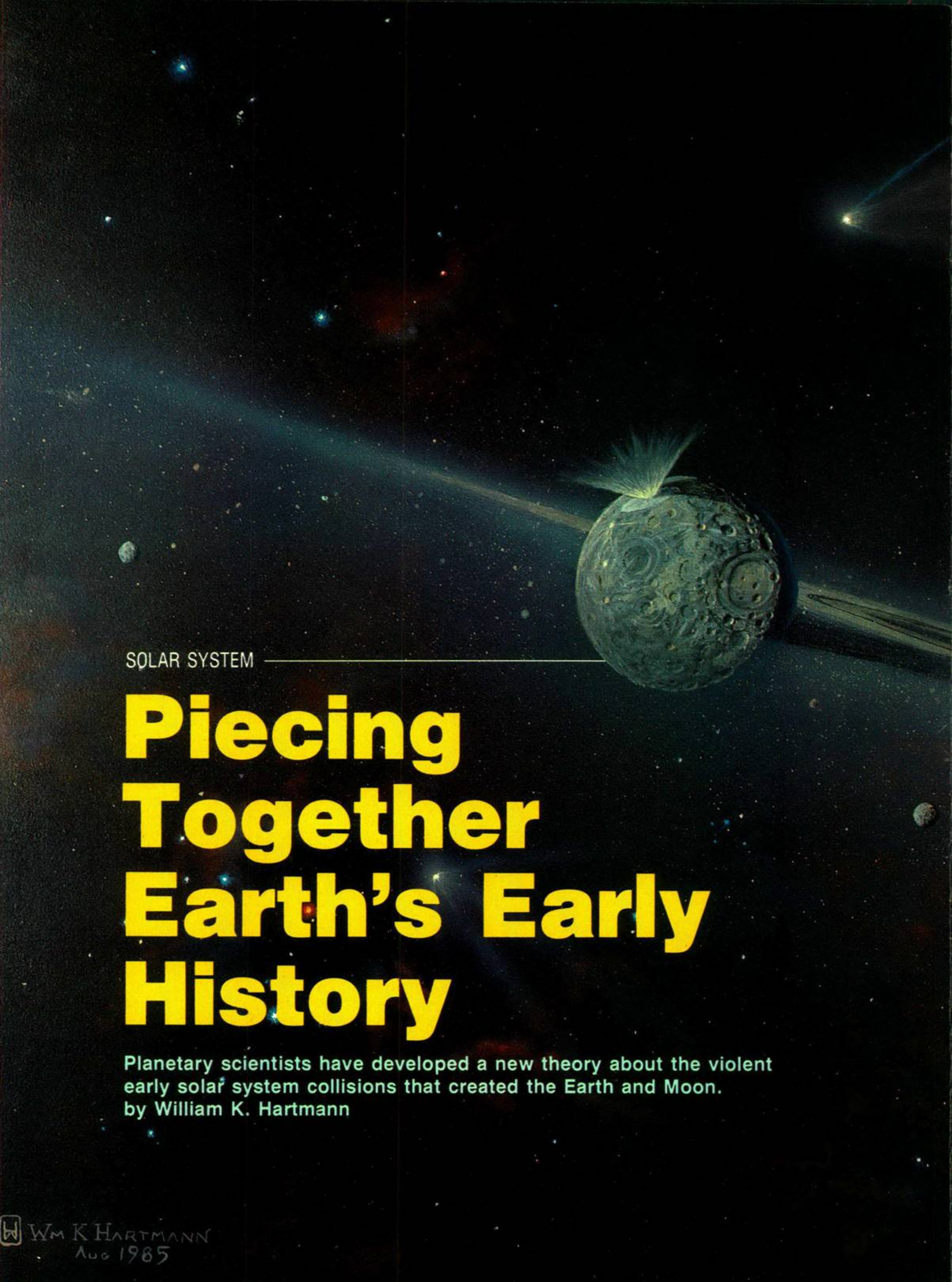
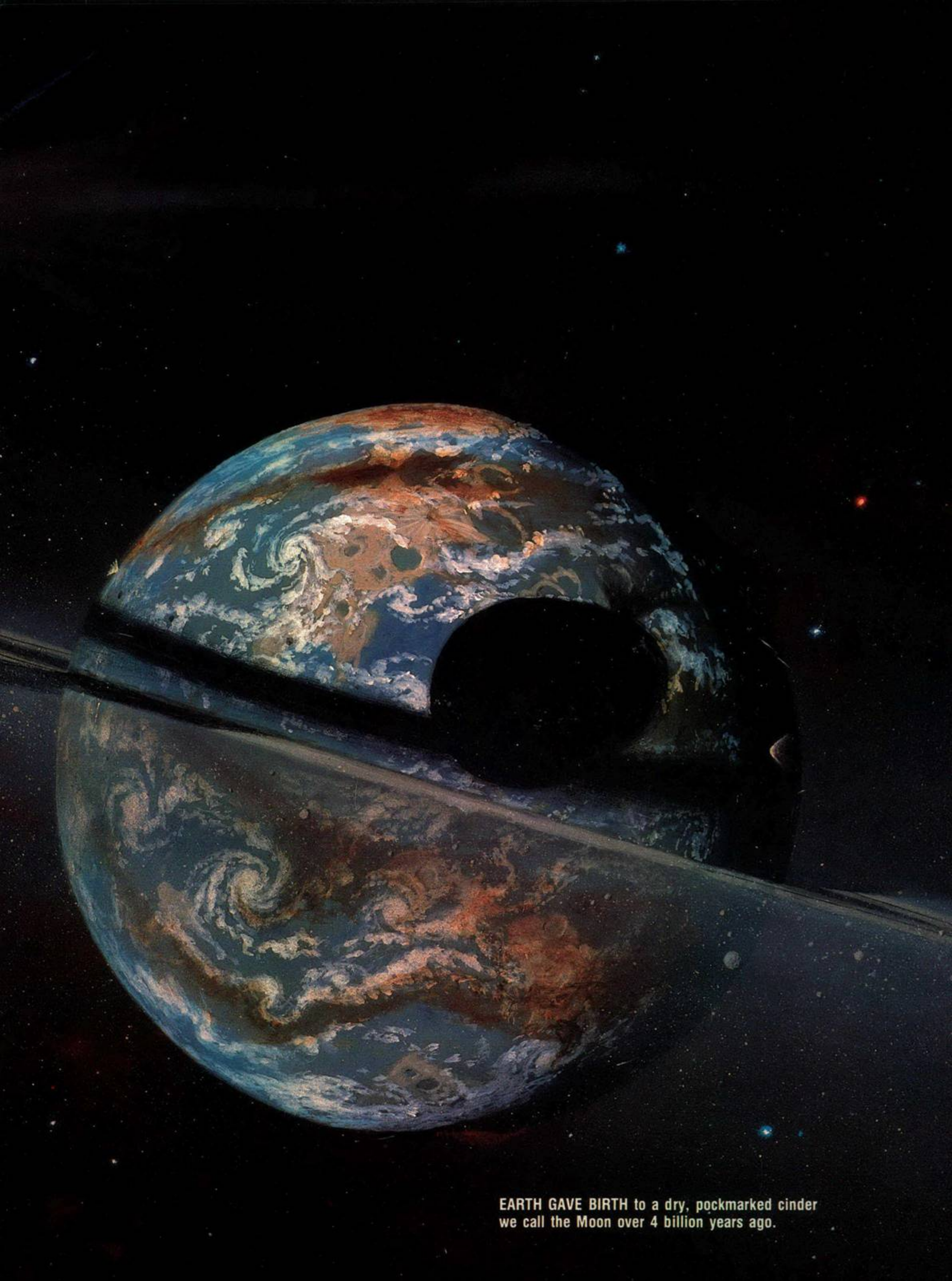


SOLAR SYSTEM

Piecing Together Earth's Early History

Planetary scientists have developed a new theory about the violent early solar system collisions that created the Earth and Moon.

by William K. Hartmann



EARTH GAVE BIRTH to a dry, pockmarked cinder we call the Moon over 4 billion years ago.

Where did Earth and the Moon come from? Scientists have been confronting this deceptively simple-looking question for decades. But it is only recently — after examining everything from the chemistry of unusual rocks to orbital calculations performed by giant supercomputers — that they have been able to piece together a realistic picture of Earth's early days beginning 4.55 billion years ago.

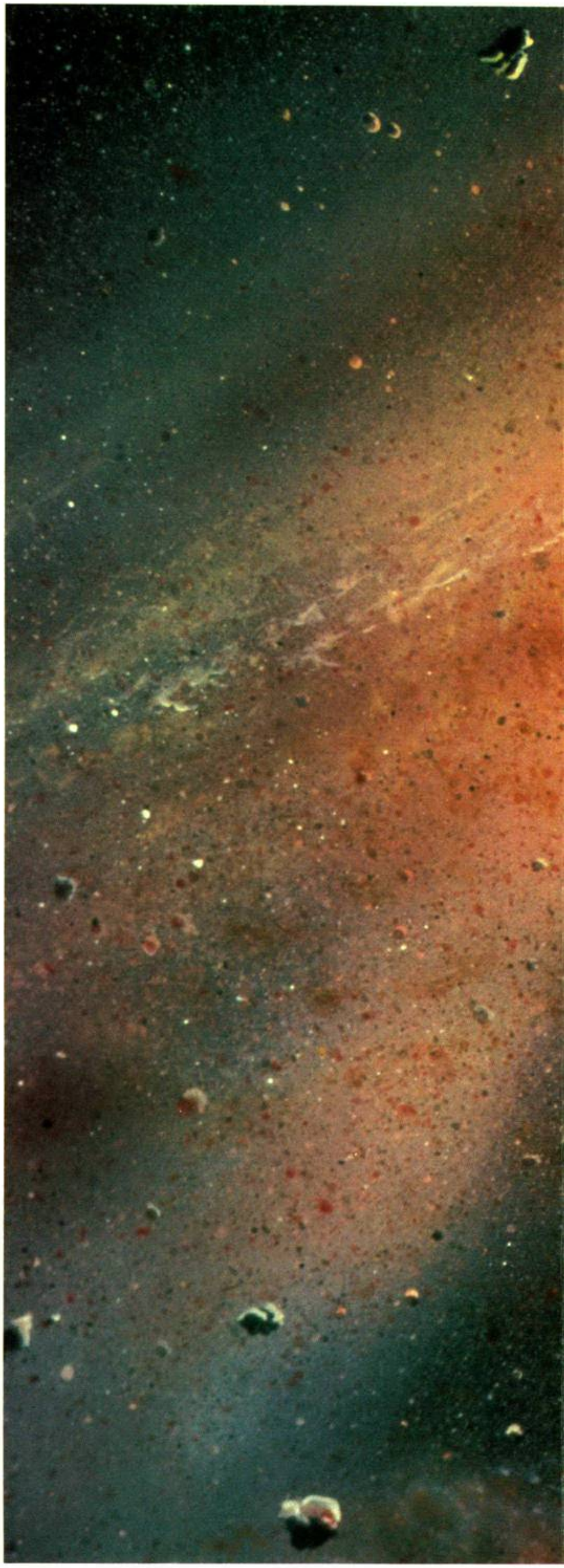
Before the 1950s Earth's origin was not understood at all. One leading theory held that giant clouds of gas, perhaps torn out of the Sun, had condensed to form each of the planets. Theorists proposed that if such clouds were massive enough and compressed enough, their own self-gravity (the attraction of one atom for another inside the cloud) would make them shrink into planets. But during the 1950s Nobel-prize-winning chemist Harold Urey uncovered one of the key chemical clues about Earth's origin — a clue that indicated Earth formed from small rocky bodies instead of from the compression of a giant cloud of solar gas.

This clue is easy to understand and is still important today. It involves the heavy inert gas elements, such as argon, krypton, and xenon. The key property of inert gases is that they don't combine easily with other elements to make compounds or rock-forming minerals, and they are typically less than a millionth as abundant on Earth as they are in the Sun. However, the planets must have formed out of the same cloud of gas and dust that spawned the Sun — the so-called solar nebula. So why doesn't Earth have the Sun's "cosmic" proportion of inert gases?

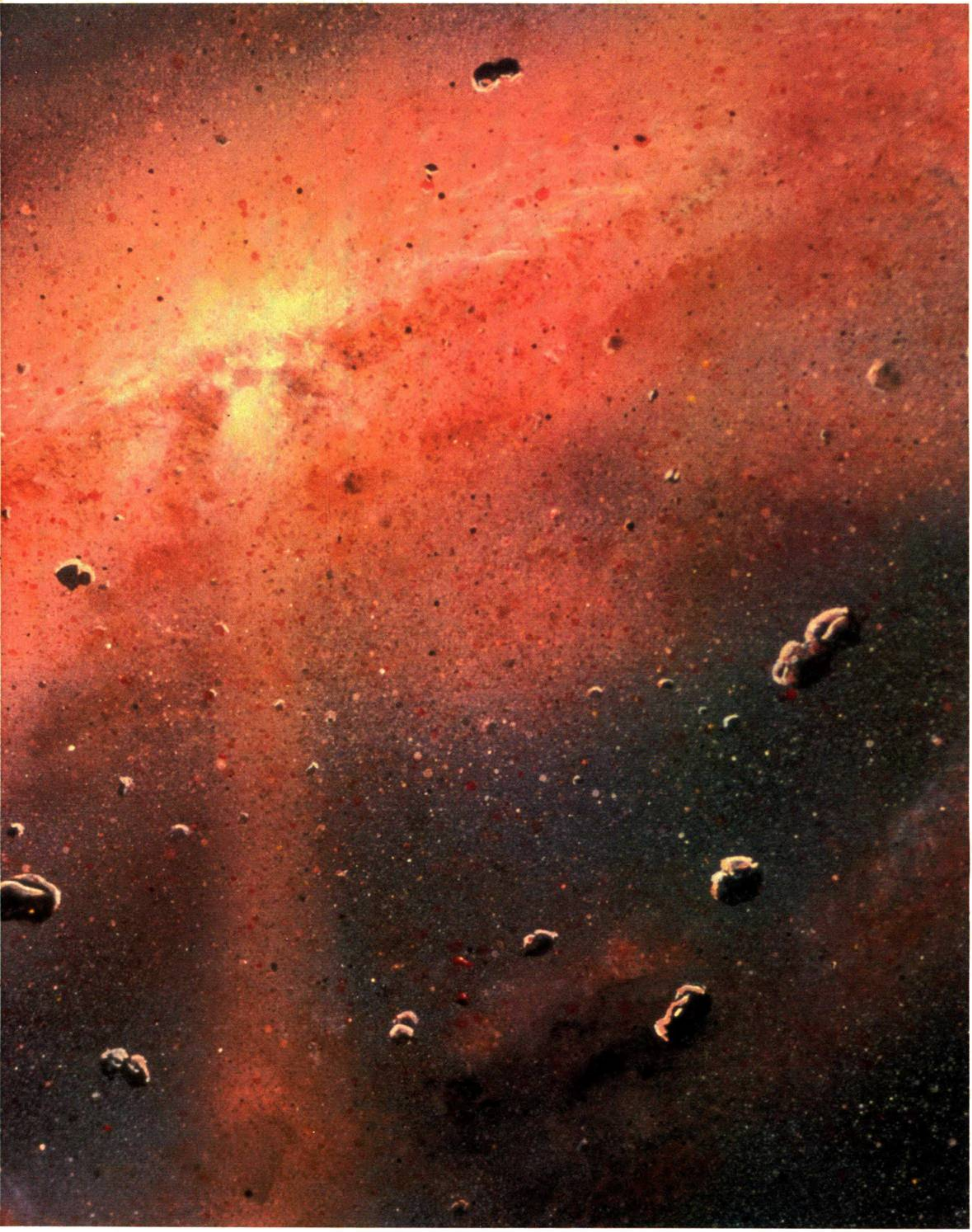
It was clear to Urey that the one-step process would have given Earth the full solar percentage of inert gases. And because these gases are too heavy to escape from Earth's gravity, we should find them today in great abundance in Earth's atmosphere and soil — and even in pieces of gravel in your driveway. Urey reasoned that the depletion of inert gases on Earth meant our planet could not have formed in a one-step process from a large blob of solar gas being compressed by gravity and then cooling. Some other method had to have been at work.

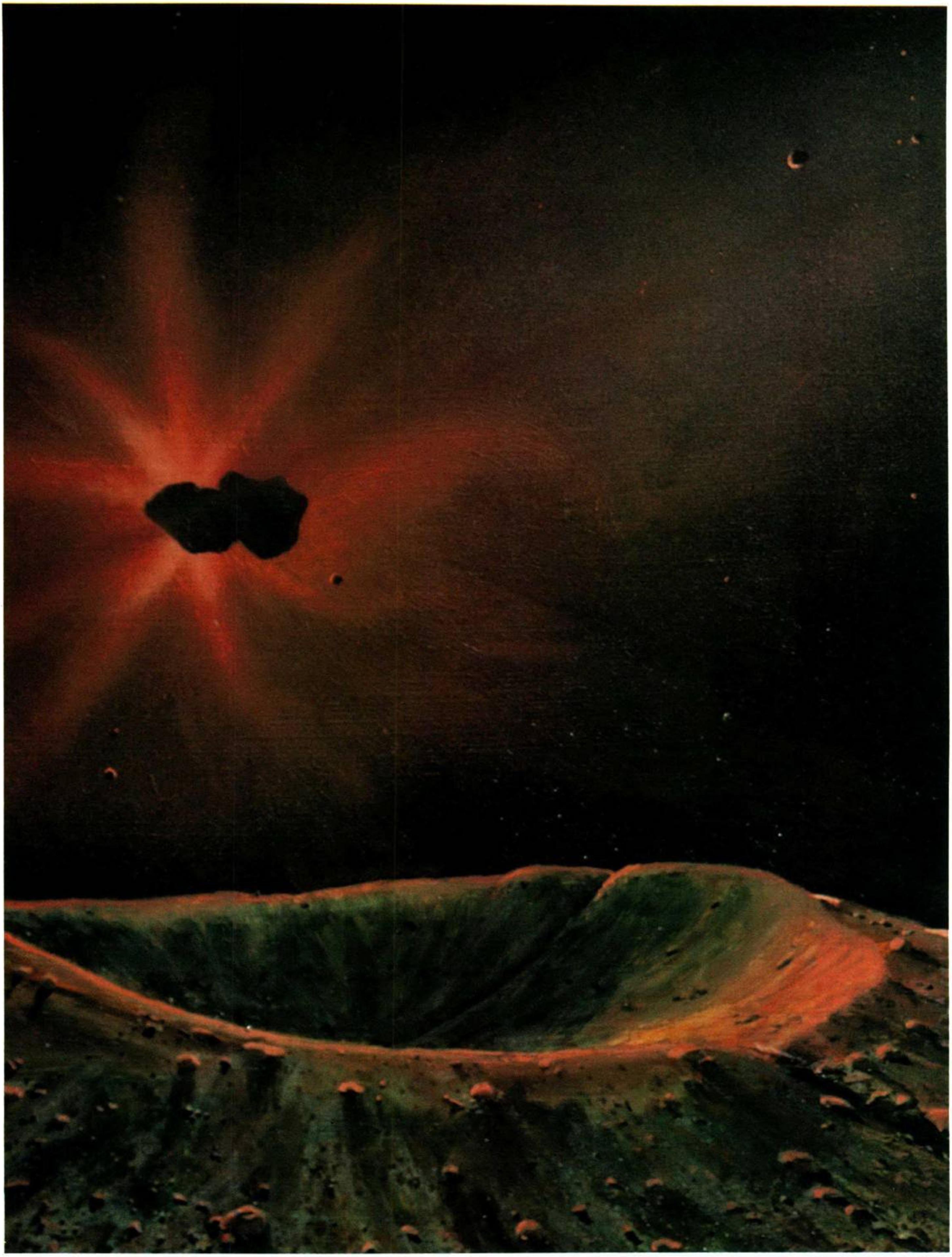
Urey solved the problem by proposing that solar nebula material aggregated first into small, rocky, asteroidlike bodies called planetesimals. Because planetesimals lack enough gravitational pull to retain inert gases, the gases soon escaped. The planetesimals then collided with one another and clumped together to produce an Earth largely devoid of inert gases.

Urey's work was based on cosmochemical studies alone. At the same time in the 1950s and 1960s, however, Soviet theorist Viktor Safronov and his colleagues were writing an important series of papers. These described how planetesimals could aggregate to produce planets with circular orbits in nearly the same plane, rotations that turn in the normal prograde way, and other familiar properties. The significant point coming out of the Soviet work was that to reproduce the tidy regularities of the solar system we see today, it was essential to assume many collisions had occurred among countless small bodies. Thus, in a curious convergence with Urey's work, the Soviets had also settled, not on giant



A VAST "FOG" OF DUSTY GAS called the solar nebula surrounded the early Sun. In it dust grains collided and stuck, slowly building small planetesimals.





masses of gas and dust, but on small planetesimals aggregating out of dust.

The Soviet theorizing was little noticed in the West until 1972, when a book by Safronov was translated by NASA. But thereafter the Soviet dynamical findings combined with the American chemical studies to spark enormous advances in our understanding of how the planets formed. Geochemists measured ever-more-precise ages of meteorites, Earth rocks, and finally Moon rocks, which showed that the solar system was born 4.55 billion years ago. Simultaneously dozens of theoretical papers drew detailed scenarios of how planetesimals would collide and clump into asteroid-sized and Moon-sized bodies.

For each such body, forming over perhaps 100,000 years, the largest "embryo" would gradually pull ahead of the rest in size. Computer modeling showed that Earth could have reached half its present mass in the first million years or so, although the growth process was slowing as asteroidlike debris was swept up by collisions with larger bodies. In the end, however, Earth must have accumulated 99 percent of its present mass in 10 million to 30 million years.

This general picture, now roughly a decade old, is still accepted. Thus, if we estimate that Earth was essentially fully formed after 50 million years, we can say that its birth took place somewhere between 4.55 to 4.50 billion years ago — a brief, narrow interval of time compared to the whole history of the solar system.

With this overall scheme in place, one of the challenges of today's planet formation studies is to fit together the geochemical and dynamical data to describe the details of the accretion process. Many geochemists believe the primitive planetesimals were rich in volatiles, chemicals that would be released as gases if heated slightly. An example is water of hydration — water molecules loosely bound in the minerals of some rocks. Dynamical studies have shown that the earliest, meter-scale planetesimals collided too slowly to generate much kinetic energy or heat. These planetesimals would have retained their volatiles and thus the first asteroid-sized Earth-embryo should have contained such substances.

Low-velocity impacts may have continued for a few tens of thousands of years after Earth began to form. But as proto-Earth grew larger, its stronger gravity began to pull in planetesimals at ever higher velocities. Impacts now were more like violent explosions, generating heat. Besides driving off the volatiles, the heat melted the surface layers as fast as they accumulated, creating a primordial surface of molten lava. This so-called magma ocean apparently formed the first surface of both Earth and the Moon. The magma ocean concept originated in the 1970s when lunar rocks showed that the most ancient lunar crust was made of light minerals that apparently accumulated as scum floating on a vast sea of lava.

As Earth grew, impact heating maintained the magma ocean, which may have been only tens of kilometers thick at any one time, with solid or partly melted rock below. The liquid state allowed denser and heavier elements such as iron and nickel to separate from the lighter rocky materials and drain downward, thus forming an iron core as the planet grew. Outside the iron core, a silicate-rich rocky layer collected, called the mantle. At the surface as the impact rate declined, the magma ocean cooled and the lightest-weight minerals formed a crust — a thin skin of granitic rock only tens of kilometers thick.

WORLDS-IN-EMBRYO, the planetesimals steadily grew as collisions built larger ones from smaller ones until only a handful of major bodies were left — the planets of today.

Earth and the Moon apparently weren't the only solar system bodies that formed hot. Evidence for this includes the fact that basaltic achondrites, a type of meteorite that resembles lava and is formed by melting, were created only about 20 million years after the planetesimals formed, or about 4.53 billion years ago. Though some of the necessary heat to melt them may have come from impacts, additional heating probably derived from some other source. A leading candidate is electrical currents caused by the interaction of the object with a vigorous solar wind from the primitive Sun — a kind of natural microwave cooking. But whatever the heat source, evidence is strong that planets and planetesimals of the inner solar system were very hot and at least partially melted very early in their history.

A decade ago scientists thought that the astronomical part of the process ended after the first 20 million to 50 million years. The rest of Earth's story, they thought, was simply geology, where internal processes such as cooling and crust formation dominated. But now we come to one of the most revolutionary ideas that has changed our conception of Earth and its satellite.

The roots of the idea go back to the 1960s. Viktor Safronov in his papers on planetary aggregation had pointed out a curious fact: When countless small bodies accrete into one planet, a few additional big bodies also grow. We can see this situation "frozen" in the asteroid belt today. The largest asteroid, Ceres, is 1,000 kilometers across, twice as big as the second-biggest asteroid. There are several asteroids in the size range of a few hundred kilometers and thousands smaller than 100 kilometers.

Safronov noted that by the time a full, planet-sized primary body had grown at a certain distance from the Sun, a few moderate-sized secondary bodies would also have grown nearby. Most of the impacts on the big planet would come from the small planetesimals and, as mentioned before, their net effect is to produce regularities such as circular orbits, perpendicular rotation axes, and prograde rotation. But Safronov observed that when one of the moderate-size secondary bodies hit the primary body, the blow would be big enough to produce a random irregularity, such as tilting the axis of the planet. Safronov suggested, for example, that the 98° axial tilt and retrograde rotation of Uranus was caused when the planet was hit late in its growth by a secondary planetesimal several percent as massive as Uranus itself.

Thus a paradox arises: while countless small bodies were engendering an overall tidiness in the solar system, collisions among a few large bodies introduced a certain degree of *un*tidiness. Or in the words of Harvard geophysicist Ken Goettel, two sides of the planet-forming process were competing to have the last word, one being "nice," the other "nasty."

In the mid-1970s Donald R. Davis and I, together with other researchers such as George Wetherill, Al Cameron, and William Ward, were extending these ideas. In 1975 Davis and I studied the sizes and effects of these moderate-size secondary bodies. We argued that the largest secondary body ever to hit Earth was so large that it was definitely untidy — nasty, even. It hit Earth after the iron core had formed (and, we now realize, after the impactor's core had also formed). The impact blew off a huge incandescent cloud of Earth's mantle material, some of which went into orbit around Earth and formed the Moon.

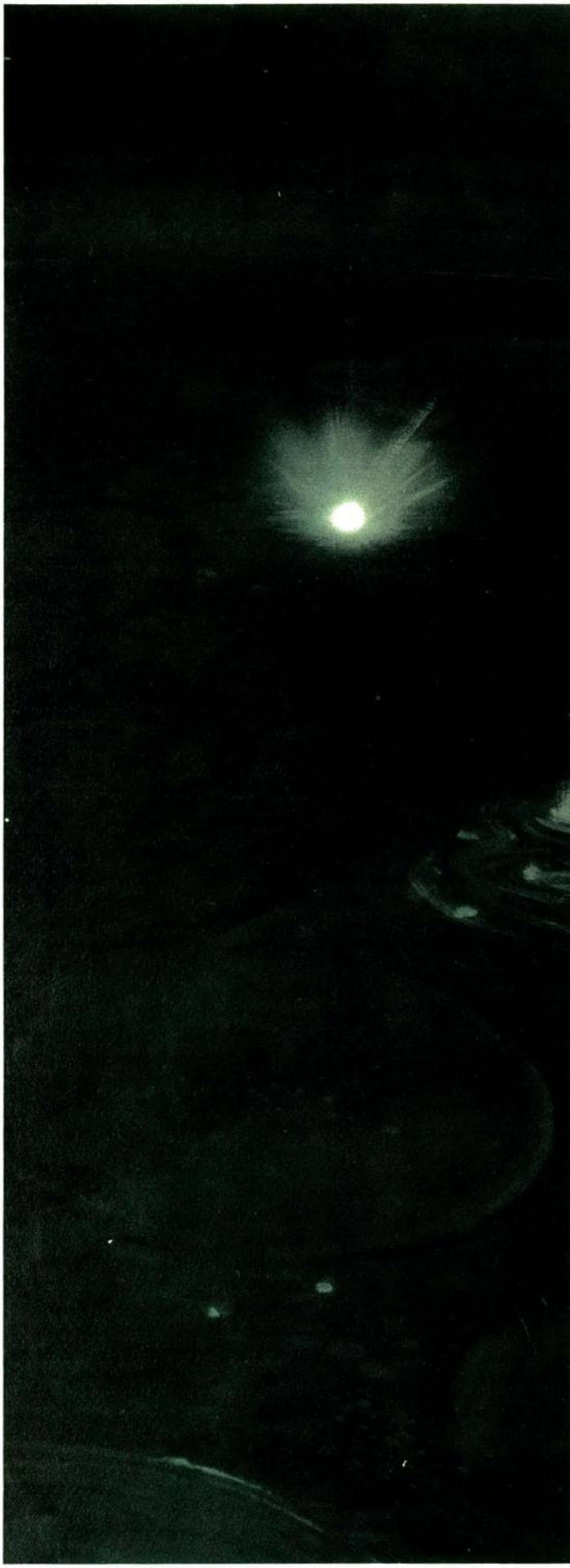
This new theory neatly explained the chemical properties of lunar rocks, which *Apollo* samples had shown to be greatly deficient in iron and volatile elements. But these lunar peculiarities, hard to fit into pre-*Apollo* theories for the Moon's origin, fell into place when we proposed that the Moon was made from Earth rocks that had already had the iron drained out of them and that were too hot to retain water and other volatiles. In 1976 Al Cameron and William Ward independently published the same basic idea, arrived at from studies of the angular momentum of the Earth-Moon system. Their work also led them to estimate that the secondary impactor was roughly the size of Mars.

At the time the theory was criticized as being too *ad hoc*. We were, after all, conjuring up a giant body out of the blue just to explain the Moon. It wasn't until about five years ago that a wide group of scientists, working with computer-simulated solar systems, began to realize that the early system probably *did* have many large secondary planetesimals flying around and colliding with the planets. This gave our ideas a crucial respectability, because giant planetesimals were no longer just a wild speculation dreamed up specifically to explain the Moon. With startling suddenness the giant impact theory emerged in 1984 as the leading theory to explain the Moon.

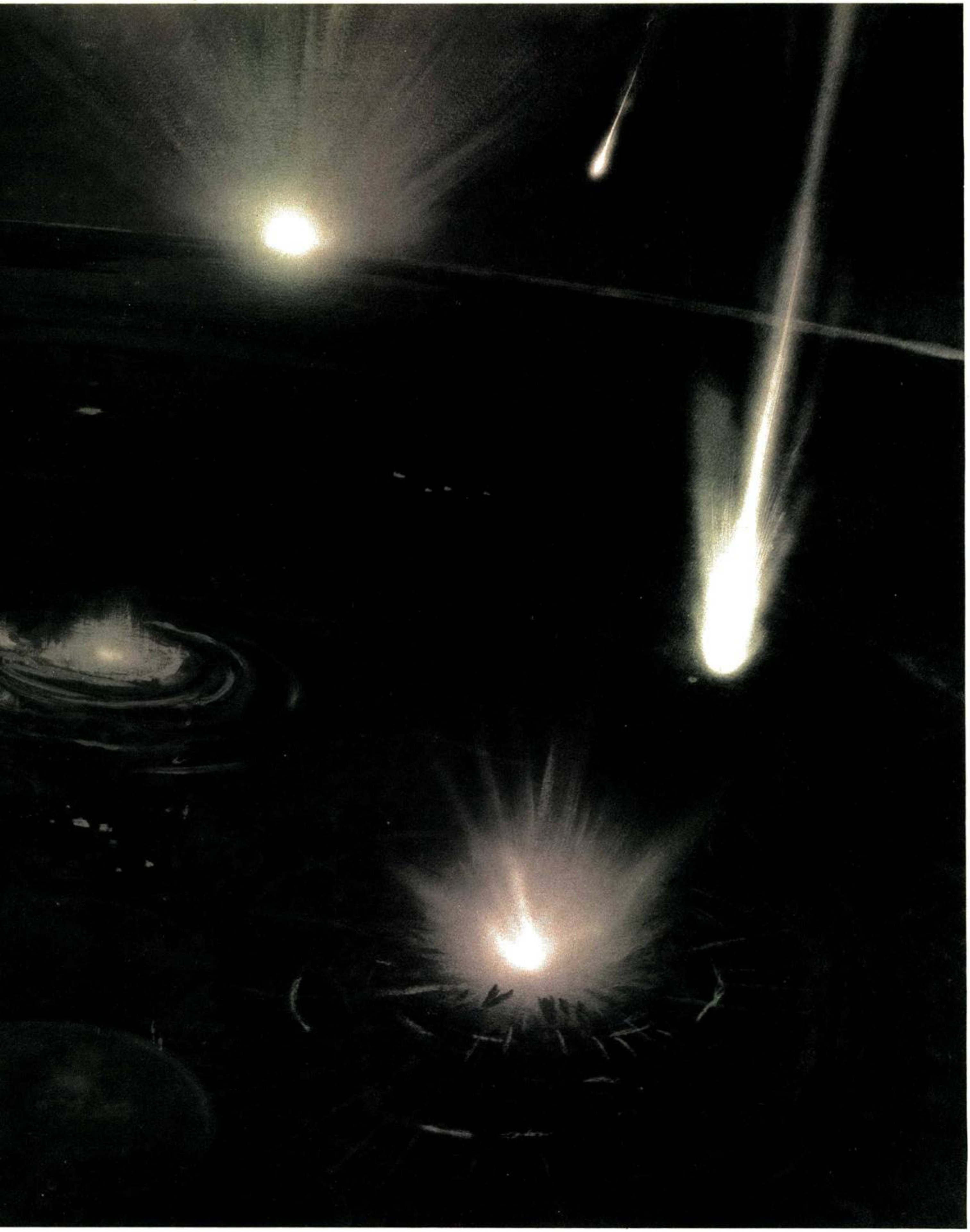
But what an impact — and what a change in our theories for the formation of Earth! Al Cameron, together with Arizona geophysicist Jay Melosh and other associates, went to work with the supercomputers at Los Alamos and Sandia National Laboratories in New Mexico to calculate what happened during the moments of collision. Using software originally designed for military purposes, these classified number crunchers could model giant impact explosions.

The results of the scientists' years of work include a simulation that details the collision process as it unfolds over a period of several hours. The calculations show that the impactor probably struck a glancing blow, shearing off much of the mantles of primordial Earth and the impactor itself in a stupendous cloud of luminous vapor. Initially most of the iron core of the impactor traveled on, though slowed by the impact. But unable to escape Earth's gravity, it looped back to crash into the disrupted Earth, eventually merging into our planet's core. Much of the mantle debris from both bodies also crashed back onto Earth. But a small fraction of the mixture of both objects' mantles stayed in orbit where it eventually coalesced to form the Moon.

The Cameron-Melosh simulation greatly interested geophysicists because it predicted that Earth's mantle would have been melted. The shock of the impact would have dumped so much energy into Earth that



AN OCEAN OF MOLTEN ROCK covered a globe on which granite proto-continents floated like rafts. Hammerblows from continued impacts kept the "ocean" liquid.



most of the mantle had its temperature raised perhaps to more than 2000 kelvins, far above the melting point of its rocks. According to the ideas prevalent in the 1960s and 1970s, scientists had thought the mantle had been heated during Earth's formation but only barely to the rocks' melting point — around 1300 to 1500 kelvins. This was hot enough to melt the iron and let it drain through the slushy grains of mantle minerals to the center where it formed an iron core, but it was not nearly hot enough to melt the entire mantle.

Here, then, was a geochemical test of the giant impact theory. If a giant impact had occurred, the subsequent melting would have been the first *complete* melting that any of these rocks had experienced since accreting into planetesimals. This would provide a chance for elements and compounds to circulate freely in a highly fluid lava, where they would form new mineral compounds indicative of very high-temperature conditions. Any mantle that had been fully melted ought to show telltale evidence of the fact.

So the big question is, do samples of deep-seated rocks, supposedly from the upper mantle, show evidence of such conditions? In 1988 Australian researcher A. E. Ringwood and Arizona researcher Michael Drake independently argued forcefully from mineralogical evidence of uppermost mantle rocks that the Earth's mantle does *not* show signs of these very high temperatures. As Drake concluded, this means that (a) the theoretical calculations of the impact conditions are not quite right and the mantle was not so strongly heated by the impact, (b) the giant impact did not occur, or (c) we don't understand the chemical conditions that separate the elements in a molten mantle. Other geochemists scoff at the idea that we have enough good laboratory measurements of the chemical and mineralogical data to settle the case one way or the other.

Resolving the "big impact" issue is important because the formation of the Moon was the most violent event that happened to our planet since it was born. One measure of the issue's importance is the heated arguments bordering on anger that have erupted at recent meetings between geophysicists and planetary dynamical astronomers and among geophysicists themselves!

It is absolutely clear that the final story of Earth's early history will come from combining both kinds of data. But for the time being the two disciplines tend to work in isolation and argue at conferences. NASA researcher John Jones, a recent student of Drake's, made the tongue-in-cheek but provocative comment that "physics shows only what might have happened, whereas chemistry shows what really did." And yet the geochemical sessions of recent conferences have featured disputes between speakers from different laboratories who had conflicting measurements or interpretations of the same chemical data.

Geochemists have also been shaken up by a new estimation of the abundances of elements in the primordial material. (Element abundances, remember, lay at the center of Urey's hypothesis that Earth formed from small planetesimals.) The dramatic new result, based on spectral measurements of elements in the Sun and spacecraft sampling of atoms in the solar wind, is that iron is considerably more abundant in the Sun than had been thought. According to many geochemists, this means that Earth and other planets probably started out with more iron than anyone thought. This in turn has changed some models of the mantle. Caltech geochemist Don Anderson argues that the lower mantle has more iron oxide and is more isolated chemically from the upper mantle than has been thought. Once again Earth's mantle is the focus of research and controversy as scientists probe Earth's structure and evolution.

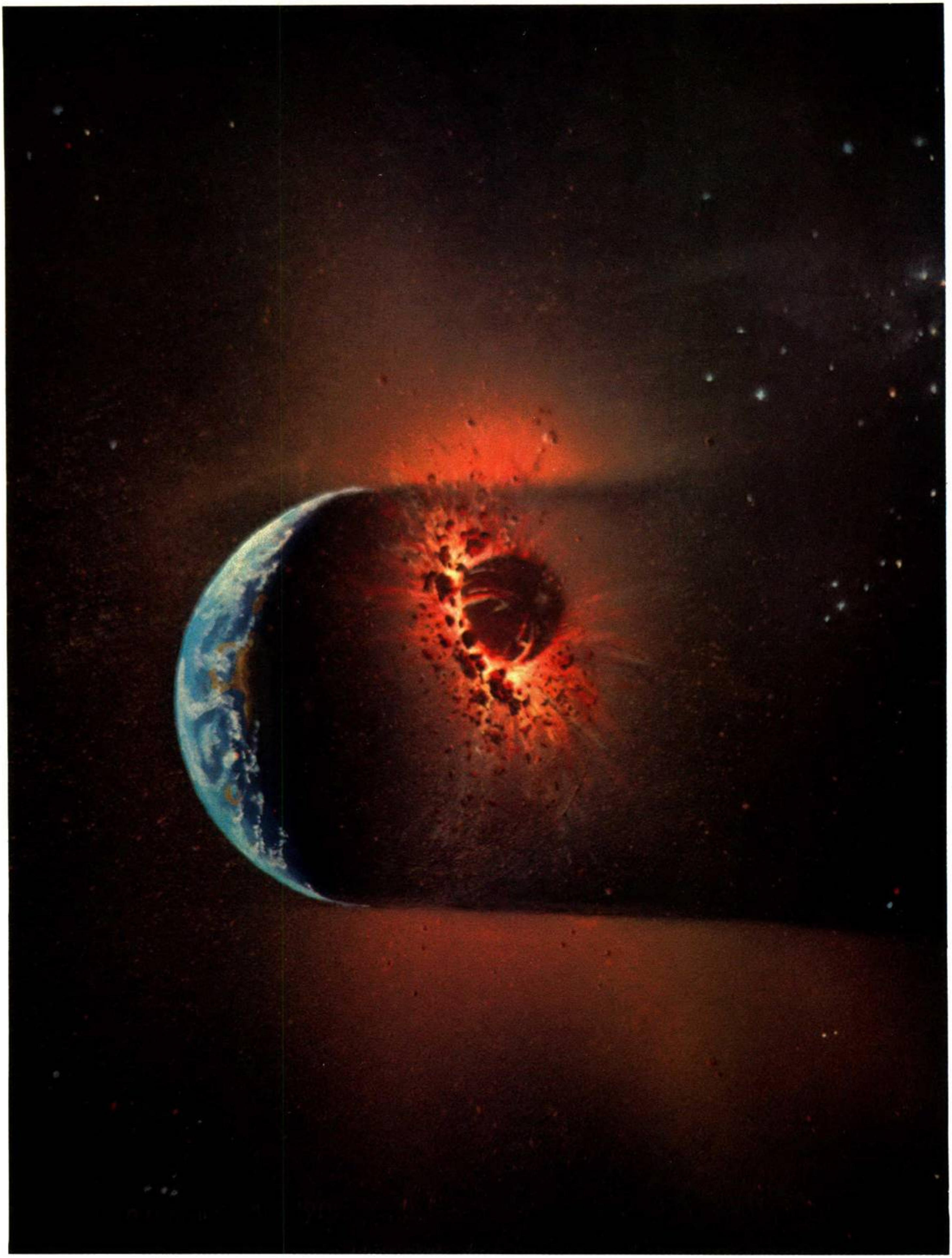
But rather than get drawn too far into these detailed arguments, let's step back a moment and summarize how our knowledge of what happened after Earth formed has advanced. The giant impact that made the Moon must have happened as the remaining planetesimals were being swept up — within perhaps 20 million years of the time Earth had reached most of its present mass. It probably happened between 4.40 billion and 4.45 billion years ago, a 50 million-year span. The hot mantle debris that was blown into orbit accumulated into the Moon in the blink of a cosmic eye. Aggregation of a satellite near a planet happens millions of times faster than the aggregation of a planet in orbit around the Sun because the orbit times are faster. The Moon, therefore, probably formed in a few tens of thousands of years. New evidence in this direction comes from a 1988 dating of one of the oldest samples of lunar crust by geochemists Richard Carlson and Gunter Lugmair. This lunar crust turns out to be 4.44 billion years old, give or take 2 million years. This means that the Moon must have formed and its magma ocean had cooled enough to create a solid crust by 4.44 billion years ago.

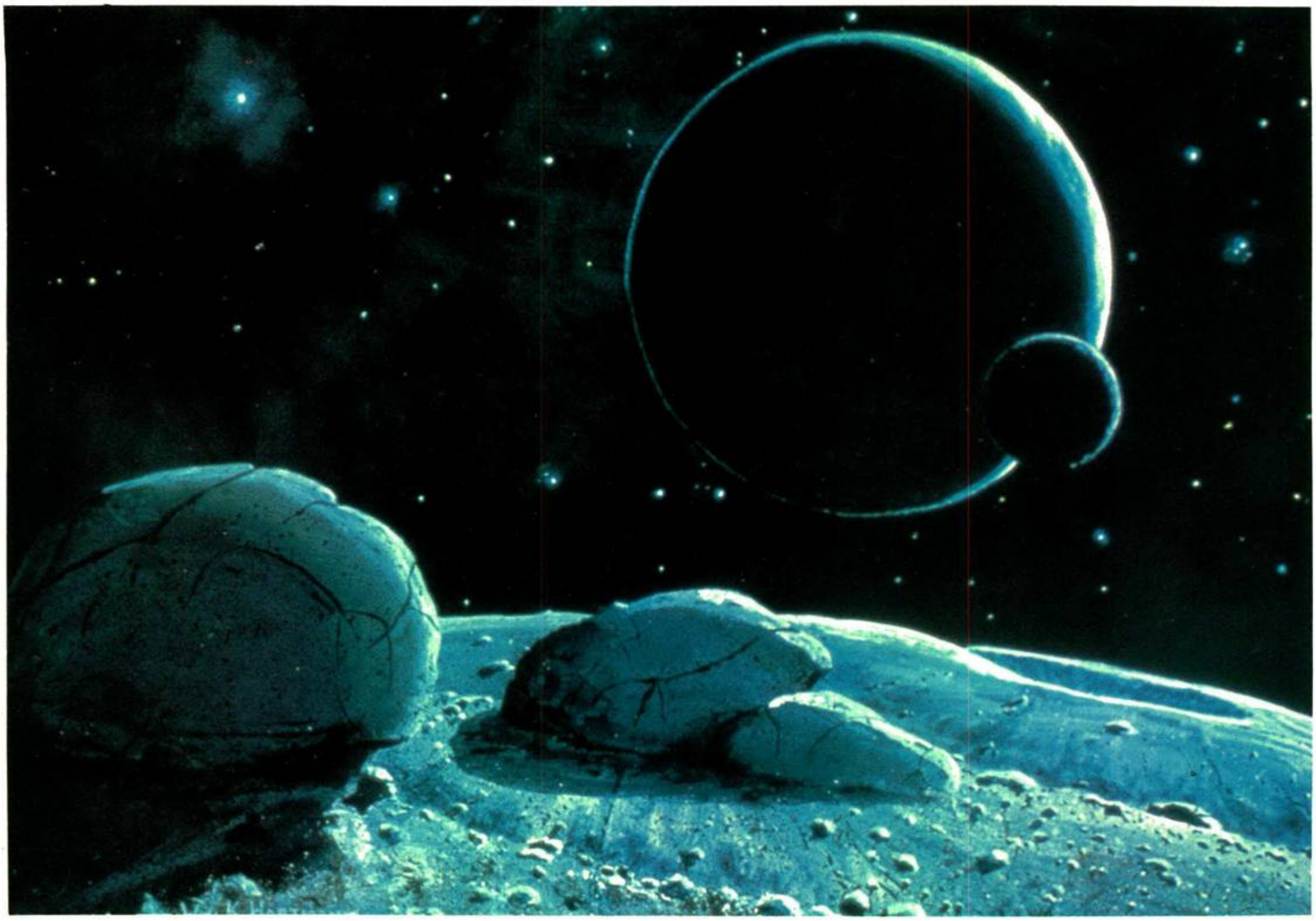
The early Earth and Moon were subjected to an intense though steadily declining rain of meteorites that ranged from a few gigantic blasts to billions of tiny pinpricks. The rates in the early days, however, were enormous by comparison to those of today: if you want to assemble an Earth in 30 million years, you need impacts occurring a billion times more often than they do today. Impacts big enough to keep all of Earth's skies darkened with dust palls happened *every month* during our planet's first hundred million years or so.

By 4.3 billion years ago the impact rate had dropped a thousandfold to perhaps a million times today's rate. And by 4.0 billion years ago it had fallen to about a thousand times today's rate. This means that although the magma oceans of Earth and the Moon were cooling and solidifying, the new-formed crusts were occasionally punched through by 1,000-mile-wide craters — basins the size of the Moon's Mare Imbrium. In some places the mantle was exposed, while in others crustal debris piled up in overlapping rims of impact basins. Perhaps such crustal debris piles were the forerunners of today's continental blocks.

Certainly a recognizable but deeply scarred crust had formed by 4.2 billion years ago, the date of Earth's oldest known rock crystals. These are hard to find today because geologic activity together with the early rain of meteorites has destroyed nearly all trace of early rocks. The earliest intact rocks found so far on Earth date from only 3.9 billion years ago — unquestionably ancient but still dating from long after the worst of the impacts were over. On the Moon, similarly, the heavy pulverization by impacts tended to destroy the oldest lunar rocks.

A GIANT PLANETESIMAL STRUCK the newly formed Earth about 4.4 billion years ago, blowing off an enormous cloud of vapor out of which condensed the Moon.





A BIG IMPACT IN OUR FUTURE? Several asteroids dozens of miles in diameter now orbit the Sun on paths that could collide with Earth or the Moon on some distant day.

If the first few hundred million years of Earth's history were dominated by giant impacts, these impacts probably influenced the climate and perhaps even delayed the origin of life. In any case life must have begun before 3.5 billion years ago, because that is the age of the oldest well-recognized microfossils.

It is hard to envision life emerging at a time when heavy impacts were common. Environmental scientist James C. Walker has suggested that the early Imbrium-scale impacts that occurred intermittently may have caused several extinctions of the earliest lifeforms but after each such event, life restarted. Sketchy evidence for such an idea comes from the observation that later fossils (such as at 3.1 billion and 2.7 billion years ago) may not be descended from the earliest fossil species. The creation of life may thus have begun and ended several times over before the rain of impacts decreased enough to let life endure.

The atmosphere during this period was very different from that of today, though scientists disagree about the details. Certainly the atmosphere had much less oxygen because plants did not yet exist to produce it. Some scientists believe the primordial atmosphere was rich in poisonous gases, such as methane and ammonia, that would have formed directly from the hydrogen-rich nebular gases that surrounded the accreting Earth.

Eventually, however, came what Walker calls the most profound transition caused by life on Earth. This occurred about halfway through Earth's history, about 2.5 billion to 2.0 billion years ago. Abruptly the oxygen content of Earth's atmosphere dramatically shot up, thanks to the oxygen produced by the newly evolved plants. Earth was soon transformed into the familiar but uniquely oxygen-rich planet it has been ever since.

Our picture of Earth's early days has become much clearer than it was even ten years ago. But so many important problems remain that the subject is far from closed — witness the mantle controversies alone. Research on early Earth continues to evolve: probably the two most important new concepts emerging in the past year are the idea that giant impacts significantly affected Earth's early history and the new measurement indicating that Earth's lower mantle structure may have a higher total iron content.

One prominent planetary geologist remarked that he has lived through two major geological revolutions: the revolution that recognized continental drift and plate tectonics in the 1960s when he was a student and the revolution that recognized possible catastrophic impacts as important in Earth history — a revolution that is happening now. ☐

William K. Hartmann is an astronomer known for his work in planetary evolution. He is also a writer and painter. His latest book, written with Ron Miller and Pamela Lee, is Cycles of Fire, *an illustrated description of stars and galaxies published by Workman Publishing Co. He is now working on a book about Earth's history.*

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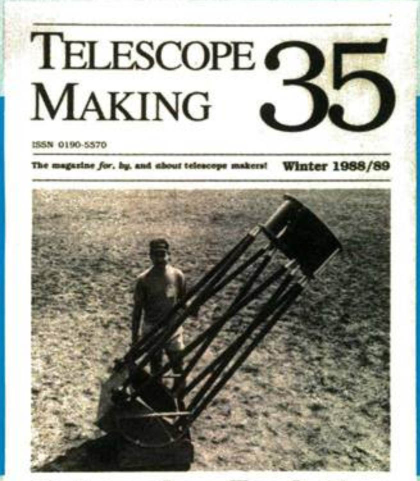
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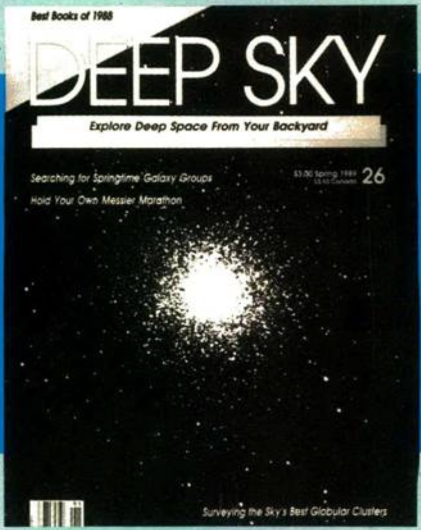
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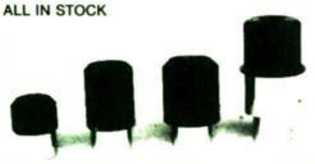

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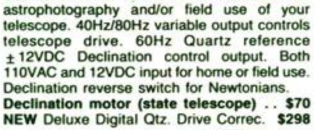

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LUMICON SKY VECTOR™ computer, showing digital readout of coordinates, and easy-to-use controls. Shaft encoders are included (not shown). The coordinates are for Minkowski 1-79, a 13th mag. planetary nebula.

The LUMICON SKY VECTOR™ is a computer-controlled digital setting circle system. It represents a break-through in both computer performance and low price. To find an object just move the telescope until the coordinates of the SKY VECTOR™ match those of the object desired.

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- Just sight two stars!

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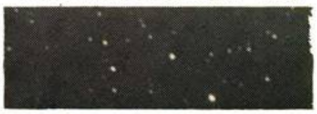
Coma 1 inch off-axis 17½" f/4.5



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LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
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1.5x, 1.8x MULTIPLIER LENS

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. It multiplies by 1.5x without the included extension tube. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.5x/1.8x multiplier lens	**$235.00**

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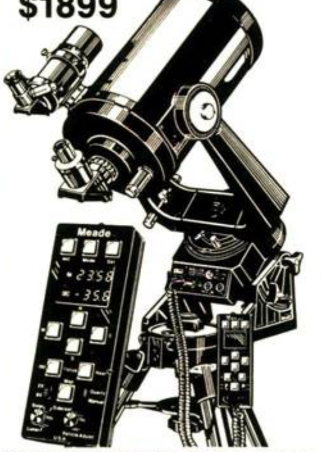

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#39 declination motor for LX5	**$109**
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LUMICON EASY-GUIDER for 2080	**$225**
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MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
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Minus Violet	420nm-IR	96%	**$29**	**$18**
Blue Tricolor	340-470nm	80%	**$35**	**$18**
Hi Perf. Blue	300-540nm	95%	**$35**	—
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Green	490-590nm	60%	**$18**	**$18**
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25mm Cross-hair 1¼" eyepiece (12X)	**$29**
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These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

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From Idea to Observation: The *Space Telescope* at Work

An astronomer's request for observing time on the *Hubble Space Telescope* sets off a complex sequence of scheduling, observing, and data analysis.

by Ray Villard

Astronomy stands on the threshold of a new era. When the *Hubble Space Telescope* reaches orbit — an event now scheduled for December 1989 — astronomers will get unprecedented views of the universe. The *Space Telescope* will see objects ten times more clearly than the largest ground-based telescopes ever will.

This clarity is possible because the *Space Telescope*'s low-Earth orbit carries the instrument above our turbulent atmosphere. Yet this liberating orbit creates its own problem: our planet becomes a moving celestial body that blocks a large and ever changing portion of the telescope's view of the universe. Also, the telescope's constant motion, along with the telescope's small field of view, makes pointing the telescope extremely difficult.

As a result, operating the *Space Telescope* is a time-consuming challenge that demands exhaustive planning, complex computer software, and intricate spacecraft maneuvers. To efficiently use the observing time available to it, the telescope must also operate automatically, without direct control from the ground.

Getting a Clear View

The *Space Telescope* circles Earth in an orbit only 360 miles high. From that vantage point, Earth blocks, or occults, nearly half of the sky, so most objects disappear from view for nearly half of each 95-minute orbit.

Besides being an obstacle, Earth can ruin deep-sky exposures because it is so bright. The telescope cannot observe objects when they are within 20° of the bright limb or 5° of the dark limb of Earth. For the same reason, the Sun and Moon must be avoided by the spacecraft's extremely sensitive detectors. To keep solar glare out of the telescope's optical assembly, the telescope cannot point within 50° of the Sun's limb.

The Sun creates a number of other constraints that, if violated, could seriously damage the telescope. For example, if the telescope accidentally looks directly at the Sun, it would seriously damage the optical assembly. A solar sensor located near the aperture door prevents this from happening by automatically closing the door if the telescope strays within 20° of the Sun.

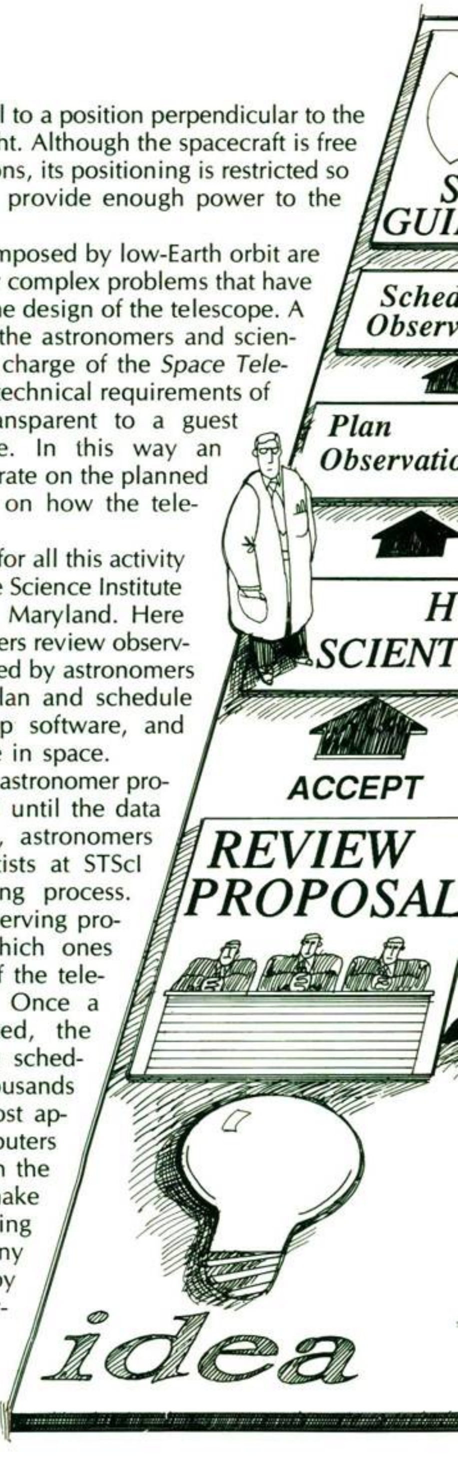
Although the *Space Telescope* must avoid observing close to the blinding glare of the Sun, the spacecraft's solar panels, which provide power to its science instruments, computers, and pointing control system, must constantly face the Sun. Normally the solar panels face toward the rear of the telescope and can sweep from a position nearly parallel to a position perpendicular to the telescope's line-of-sight. Although the spacecraft is free to move in all directions, its positioning is restricted so that the solar panels provide enough power to the spacecraft.

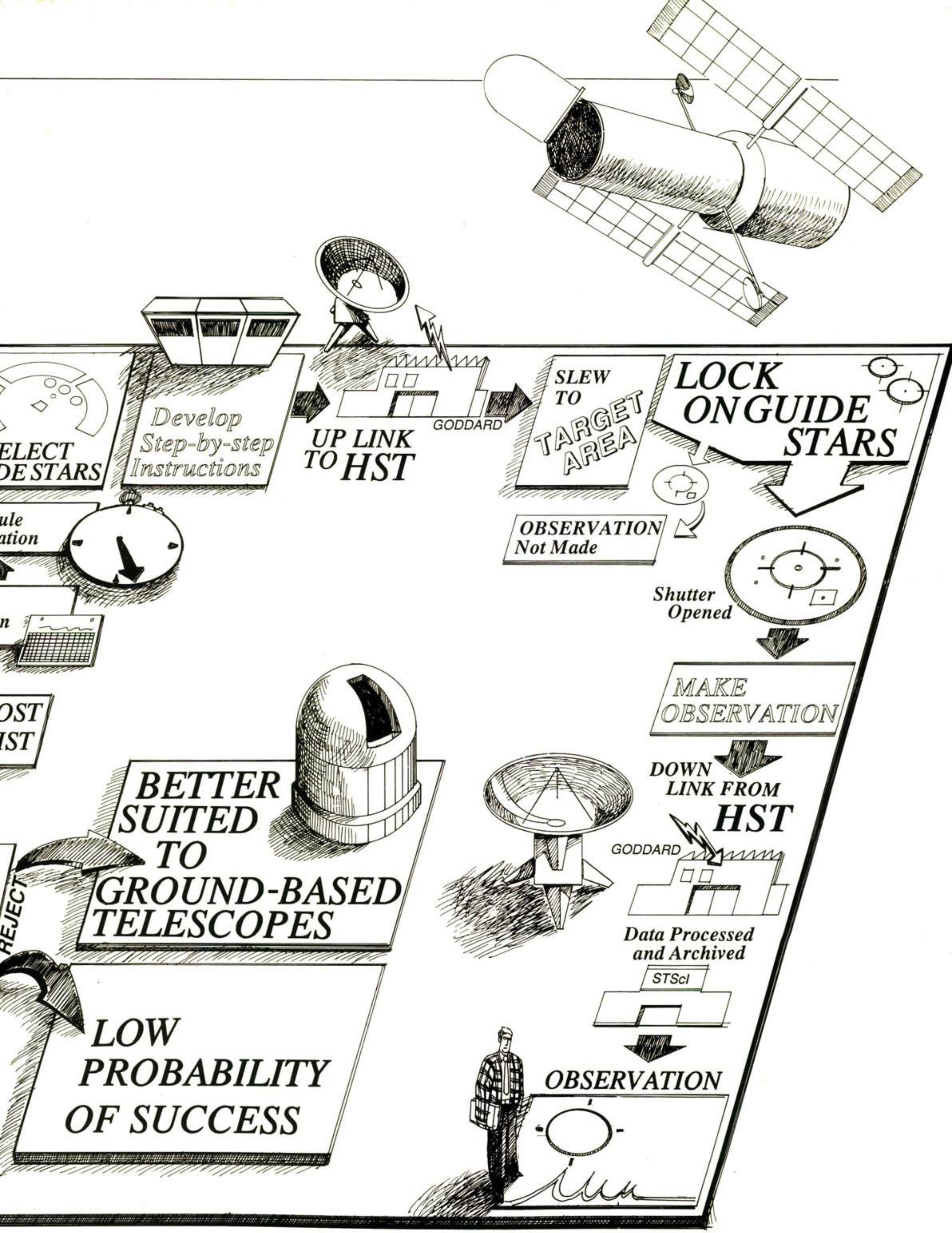
The restrictions imposed by low-Earth orbit are just a few of the many complex problems that have been considered in the design of the telescope. A fundamental goal of the astronomers and scientific programmers in charge of the *Space Telescope* is to make the technical requirements of the telescope as transparent to a guest observer as possible. In this way an observer can concentrate on the planned observation and not on how the telescope operates.

The nerve center for all this activity is the Space Telescope Science Institute (STScI) in Baltimore, Maryland. Here hundreds of astronomers review observing proposals submitted by astronomers around the world, plan and schedule observations, develop software, and operate the telescope in space.

From the time an astronomer proposes an observation until the data is returned to Earth, astronomers and computer scientists at STScI oversee the observing process. First they review observing proposals to decide which ones make the best use of the telescope's capabilities. Once a proposal is accepted, the observation must be scheduled, along with thousands of others, for the most appropriate time. Computers help determine when the telescope can best make each observation, taking into account the many constraints imposed by the spacecraft's low-Earth orbit.

After an observation is scheduled, the detailed, sec-

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ond-by-second instructions needed to operate the telescope are sent to the spacecraft's computers. Most observations are carried out without intervention from the ground, so the instructions must completely specify the planned observation. The most complicated aspect of this sequence is having the telescope lock on to the targeted object while the spacecraft is in constant motion around Earth. Data is beamed back to Earth, where the waiting astronomer gets his first look at the unique information.

Proposing an Observation

Observing time on the telescope is understandably tight — there are far more astronomers who want to do astronomy than there is telescope time available. For the telescope's first year of operation, seven proposals will be rejected for each one accepted.

The process begins when an astronomer submits a proposal to STScI. Each proposal presents a description and scientific justification of the planned observing program and an explanation of why these observations cannot be made with a ground-based telescope. The astronomer identifies the celestial target or targets, selects which of the five science instruments will be used, and indicates the types of instrument configurations or modes of operation the observation needs. This last step is no trivial task because each instrument has thousands of modes of operation that involve different filter combinations, apertures, and other parameters.

Operating the *Space Telescope* is a time-consuming challenge that demands exhaustive planning, complex computer software, and intricate spacecraft maneuvers.

All observations with the *Space Telescope* must be precisely planned in advance because the observations are normally executed automatically by a preprogrammed sequence of commands loaded into computers aboard the telescope. The telescope then operates autonomously to acquire targets, operate the instruments, and communicate with Earth.

This automatic mode of operation is necessary because of the telescope's low-Earth orbit. The telescope orbits Earth once every 95 minutes. Astronomical targets come and go far too quickly to make real-time control practical without reducing the speed and efficiency of observations. If an astronomer can justify the need, real-time observations, which allow the spacecraft to be repositioned manually with respect to a target, will be approved. Otherwise, in order to maximize the telescope's efficiency, different observing programs are interwoven so extensively that most astronomers do not have their entire observation completed in a single block of time.

In preparing a proposal an astronomer must realistically estimate how much spacecraft time is needed to make the observation. This observing time is not simply the time needed for an exposure, but also includes the time it takes the instruments to read out their data to the onboard tape recorders or downlink them directly to Earth, the time to acquire guide stars and lock on to the target, and the time to re-acquire the target if it is occulted by Earth before the exposure ends. Real-time observations add even more observing time because of the extra time needed to display the image and for the astronomer to decide how to reposition the spacecraft.

When a proposal reaches STScI it is sent to one of several peer-review committees that represent various sub-disciplines in astronomy, including planets, stellar astrophysics, the interstellar medium, and galaxies. Each panel submits a ranked list of proposals to the Telescope Allocation Committee, which consists of the chairpersons of each review panel. The committee develops a well-balanced scientific program for the telescope, then makes its recommendation to the director of STScI, Riccardo Giacconi.

Getting the OK

Once the STScI director accepts a proposal, a staff member is designated as "host scientist" and works with the guest observer on the detailed requirements of the observation. One powerful resource the Institute has available to assist astronomers in preparing finder charts for an observation is the Guide Star Astrometric Support Program. STScI created a computerized map of the entire sky by scanning and digitizing 1,500 photographic sky survey plates. The resulting database contains accurate positions and magnitudes for 20 million stellar and nonstellar objects. When an observer needs the required precision, the guide star program can quickly produce a digital scan and detailed coordinates of the region under study.

Another valuable tool developed by STScI is the Proposal Entry Processor system. Utilizing artificial intelligence, this system applies four hundred "learned" rules to check proposals for redundancies, contradictions in operating procedure, or other violations of the telescopes's operating parameters.

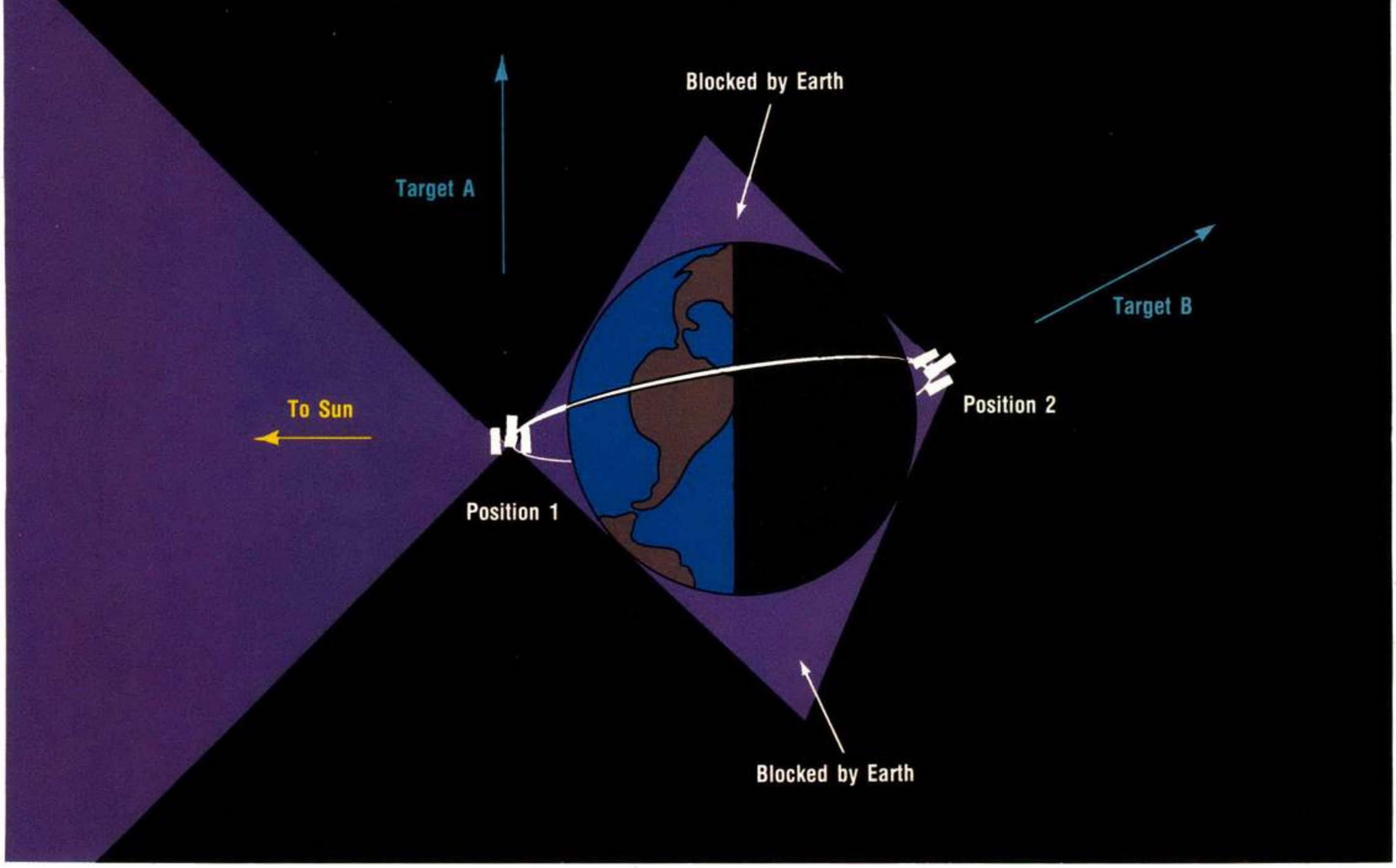
Once the planned observations are in the processor's database, they are ready to be arranged into an observing schedule. Each year the telescope will conduct some three hundred observing programs that call for several thousand individual observations. STScI programmers must schedule these thousands of observations into the approximately three thousand hours of observing time available each year.

To maximize the spacecraft's efficiency and thus the scientific return, mission planners developed the Science Planning Interactive Environment system, which uses artificial intelligence to prepare a long-range planning calendar. This system graphically displays a number of the constraints imposed by the *Space Telescope*'s science instruments, the spacecraft's orbital parameters, the allotment of observation time, and special requirements of the observer's proposal. The system then allocates an observation to the available time slot that offers the greatest chance of success.

In addition to the problems associated with the spacecraft's low-Earth orbit, the telescope's science instruments have several operating constraints. One key restriction is that the spacecraft does not provide enough electricity to power all the instruments simultaneously, at most two instruments can be powered-up at any given time. Switching an instrument on and off wastes time because it takes up to twelve hours for the instrument to reach thermal equilibrium. To minimize these on-off cycles, a given instrument will most likely be used con-

THE *SPACE TELESCOPE* CAN'T LOOK EVERYWHERE

Because the *Space Telescope* circles Earth in an orbit 360 miles high, our planet blocks a significant and ever changing portion of the sky. The telescope's sensitive detectors risk damage if the telescope points within 50° of the Sun or 20° of Earth's bright limb. This is why the telescope's schedule must be carefully planned to efficiently use the available observing time. In this diagram, the *Space Telescope* can observe target A from position 1 and target B from position 2, but not B from position 1 or A from position 2.



tinuously for several days before being turned off.

The Telescope Receives Its Instructions

When all the constraints and observing parameters have been accounted for, the long-range observing schedule is ready to be fed, week-by-week, to the Science Planning and Scheduling System. This system builds a second-by-second time line that describes every detail of the spacecraft's science operation.

A key step in this process is picking the guide stars that the telescope will use to maintain alignment during an observation. Though the observer supplies the target object's coordinates, the Science Planning and Scheduling System must identify pairs of guide stars along either side of the target. The system automatically requests guide stars from the Institute's Guide Star Catalog.

To ensure that guide stars are available wherever the *Space Telescope* points, the STScI spent five years building a star catalog one hundred times larger than any previous sky inventory. The catalog contains accurate (to within 0.3 arcseconds) positions of 15 million stars from magnitude 9.5 to 15.5.

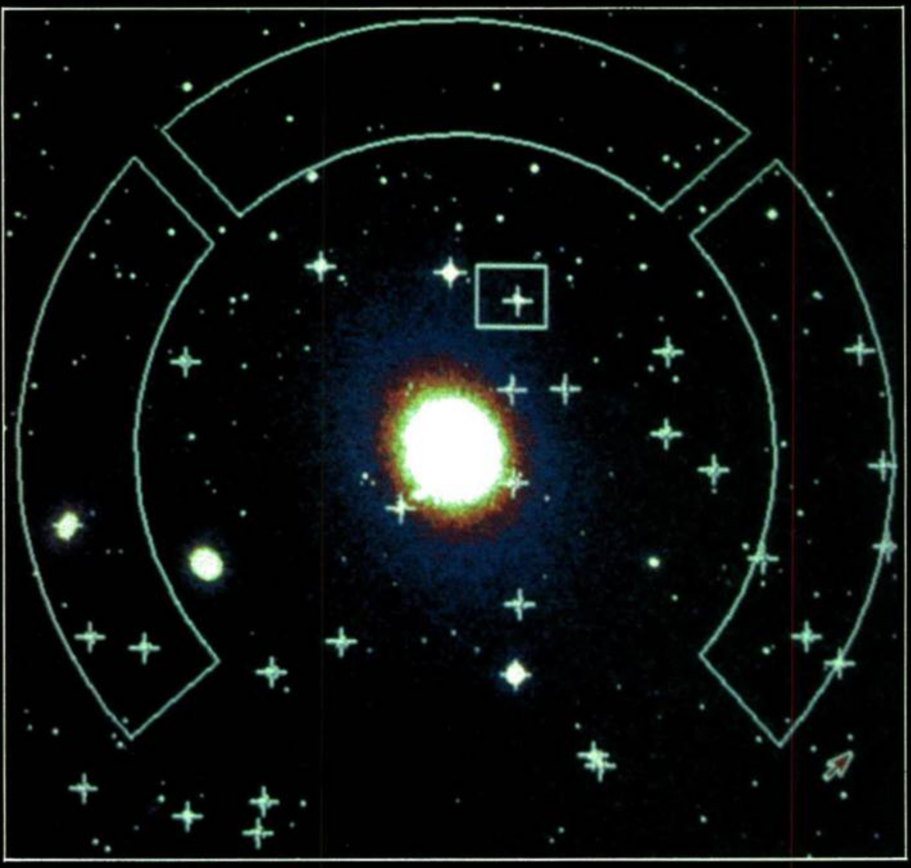
Even with such an immense pool of stars available, selecting guide stars is tricky. A guide star pair that falls perfectly into the field of view of the telescope's Fine Guidance Sensors on a given observing date will not suffice if the date is moved by weeks or months. To keep the spacecraft's solar panels oriented to the Sun, the *Space Telescope* views the sky at a continuously shifting angle. To acquire the same pair of guide stars a few months later than originally scheduled, the spacecraft would have to rotate about its optical axis. To keep a sufficient amount of sunlight falling on the solar panels, mission planners prefer to have another, more suitable pair of guide stars available if the observation date changes.

Thus, as many as thirty-five guide star candidates are sent to the Science Planning and Scheduling System. By applying complex selection criteria, these candidates are ranked from the best available to the least useful. The system inserts the highest ranked guide star pair in the mission plan, with two pairs serving as backup if the first pair can't be acquired.

The software system produces the Science Mission Specifications file. This is the script that the science instruments and related systems will follow precisely and automatically. The file is transmitted to Goddard Space Flight Center's Space Telescope Operations Control Center to be uplinked to the telescope. At Goddard the file is converted once more, into the binary machine

HOW THE *SPACE TELESCOPE* FINDS AN OBJECT

Once the *Space Telescope* is pointed in the approximate direction of the target, Fine Guidance Sensors search for guide stars. If two of the three sensors acquire the correct guide stars, the position of the telescope is "pinned" to the sky and the desired object is centered. In this simulated view the galaxy M87 is the target, the sensors' field of view forms the horseshoe pattern, and guide stars are in the sensors at left and right.



code that the *Space Telescope*'s computers read directly.

Three times each day Goddard controllers send the commands to the spacecraft, where they are stored in the flight computer and science computer. Then, like a skilled acrobat, the *Space Telescope* automatically performs an exactly timed, extraordinarily precise set of maneuvers that allow it to observe celestial objects.

Pointing the Telescope

The telescope typically prepares for a new observation when the target is still occulted by Earth. The sequence will usually begin when the spacecraft is on the sunlit side of Earth, because many targets will be observed when the telescope is deep within Earth's shadow, away from the glare of the Sun and Earth's bright limb.

The *Space Telescope*'s movement to the new target and subsequent stabilization are controlled by reaction wheels. These flywheels move the spacecraft by the transfer of momentum, so rocket thrusters (which could contaminate the telescope's optics) are not needed.

To control the wheels, the telescope's Pointing Control System sends a series of short pulses to one or a combination of the four reaction wheel assemblies. This allows the telescope to accelerate, coast, and decelerate to a new position. On-board gyroscopes sense when the telescope reaches the desired coordinates and instruct the telescope to hold steady at the new position.

Although the gyroscopes are extremely precise in small maneuvers, their positional uncertainty may be as high as a few arcminutes in slews of 90° or more. At the end of a long slew the *Space Telescope* will double check and refine its position using three star trackers. The star trackers ensure a positional accuracy within 45 arcseconds, which is not yet good enough to begin observations.

The telescope must wait for the target to rise into view before it can begin the next and final stage of alignment — the detection of guide stars. For this task the *Space Telescope* uses off-axis star trackers called Fine Guidance Sensors. Pairs of sensors search for guide stars along two of three 3.8-arcminute-wide sectors, called "pickles" by virtue of their shape, positioned in quadrants along the edge of the telescope's focal plane. (These are shown in the image above.)

The magnitudes and coordinates of the candidate guide stars are fed into each of two sensors. Next, one sensor initiates a search by moving a 2-arcsecond aperture through a spiral search pattern. Once a candidate star falls within the field of view, the sensor measures the star's magnitude and matches it against the star identified in the mission specifications to within 0.1 magnitude. When the star is found, the sensor rotates an aperture around the guide star, noting where the starlight drops off. This process pinpoints the star's position to within 20 milliarcseconds.

Because this precision is still not high enough, the sensor then goes to the next higher level of accuracy, the fine-lock stage. At this stage an optical interferometer determines how far off-axis the guide star is and the flight computer sends a command to the momentum wheels to correct the telescope's pointing.

Once the first guide star is locked-on, the *Space Telescope* is stabilized in two axes — pitch and yaw (movement left or right of the Sun). A second sensor then begins its search for a second guide star. Once the second star is found, the angular separation between the two guide stars is measured to confirm that this is the correct pair. Like placing two nails in the wall to hold up a picture, the *Space Telescope*'s field of view is now "pegged" onto the celestial sphere.

In a typical day of observing, the *Space Telescope* returns 400 million bytes of data to Earth, enough to fill an entire encyclopedia.

There are several reasons why the telescope may fail to lock on to the guide stars. Astronomers estimate that about 20 percent of the guide stars (3 million stars) are binaries that were not resolved in the ground-based sky-survey plates. When a binary is encountered, the sensors automatically search for a back-up guide star pair. There is also a slim chance that the sensors could not lock on to either the primary guide star pair or its back-ups.

If the sensors fail to lock-on to the guide stars, the science instruments will proceed to make the observation anyway. Because the telescope operates autonomously and is schedule-driven, all the instruments must still execute mechanical operations, such as filter changes, as if they were really collecting starlight.

The 0.3-arcsecond pointing accuracy provided by guide star tracking is still not adequate for some *Space Telescope* observations. Sometimes an object's coordinates are not known to within 10 percent the size of the aperture on selected instruments, and several of the instruments have apertures of only 0.1 arcsecond.

When greater precision is needed, the telescope will automatically proceed to "mode II" after the guide stars are acquired. In mode II the same guide stars are used, but the science instrument actively centers on the target and then sends a positional update to the flight computer. Depending on the instrument involved, mode II can add from 1 to 25 minutes to the target acquisition time.

In some observations even mode II does not provide enough accuracy and real-time human intervention is needed to point the spacecraft. Under this "mode I" acquisition a science instrument is programmed to transmit a first look image to the Science Operations nerve center, known as the Observation Support System, which is located in a small control room at STScI. There telescope operators continually monitor the status of the science instruments and verify that the scheduled science program is being carried out.

The operations astronomers manning the support system have a bank of computer readouts that display temperatures, voltages, and other performance parameters that might affect the quality of the data coming down from the telescope. The operators watch for any fluctuation that might indicate a potential instrument problem or malfunction. They can quickly display imaging, spectral, or photometric data and use a number of software tools to evaluate the situation.

Observing in Real-Time

In real-time observations a "first look" image from one of the science instruments is transmitted to the Observation Support System and displayed on a monitor within five minutes of guide star lock-on. Telescope operators identify the target, measure how far off center it is, and position a cursor on the screen to identify where the telescope should point next.

Time is critical in these real-time uplinks to the spacecraft. The telescope does not wait indefinitely to receive a repositioning command. After approximately ten minutes the instrument concerned will automatically begin an observation whether it is on target or not. This is necessary to keep the telescope's tightly programmed sequence of events on schedule.

Although observing at a ground-based observatory has its hectic moments, real-time observing with the *Space Telescope* is especially challenging. The success of years of planning largely hinges on pointing decisions made in the few minutes the telescope waits for a message from ground controllers.

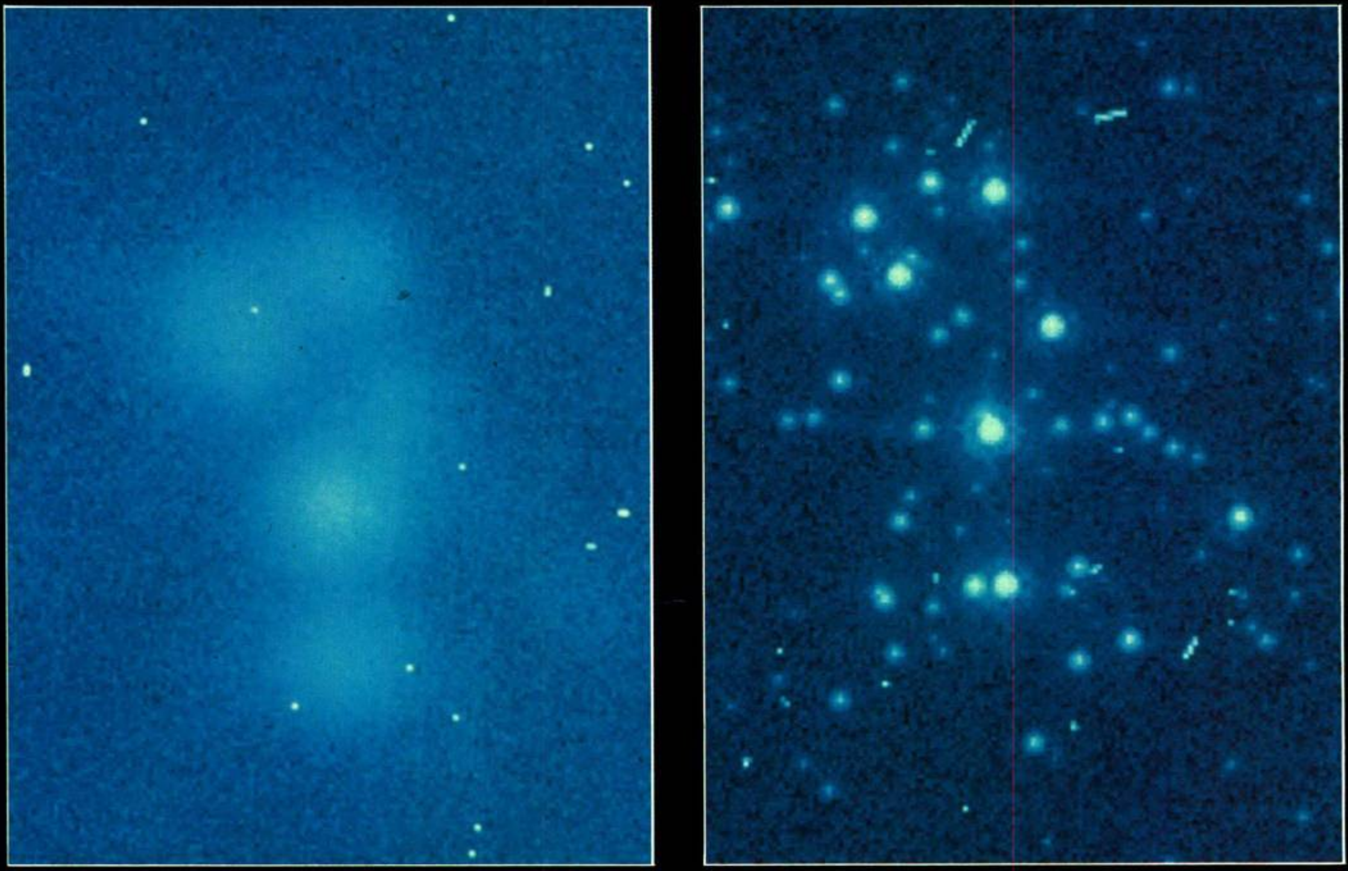
Even when the *Space Telescope* is operating without real-time intervention, an image is downlinked to the Observation Support System at the end of each observation. Orbit after orbit, operation astronomers view images and spectral data on the computer screens. This first look allows telescope operators to preliminarily inspect images to see if they were correctly exposed, contaminated by cosmic ray particles, or if the signal-to-noise ratio was high.

During a time exposure, the *Space Telescope* cannot stray more than 0.007 arcsecond from its target (a task equivalent to keeping a laser trained on a dime located 400 miles away) without smearing a star's image. And even in the seemingly benign environment of weightless space the spacecraft must continually and actively counteract a variety of forces acting on it. These forces arise from Earth's gravity and drag exerted by the atmosphere and are sensed by the Fine Guidance Sensors. When the telescope has strayed, the flight computer adjusts the spin rate of the reaction wheels to correct the problem. In many cases a given target needs to be observed longer than the time available in a single orbit. As the target sinks toward Earth's limb, the instrument's shutter closes.

Meanwhile, science and engineering data stream back to Earth at four thousand bytes per second. Real-time observations and data from the imaging systems come back at 1 million bytes per second. In a typical day of observing, the ground system will handle approximately 400 million bytes of data. If these bytes were converted into letters and words, a single day's obser-

THE CLARITY OF THE *SPACE TELESCOPE*'S VIEW

The *Space Telescope* will be able to see objects ten times more clearly than ground-based telescopes ever will. These simulated views show how the Pleiades might appear if they were located in the Large Magellanic Cloud. A 15-minute exposure through a 200-inch ground-based telescope (left) reveals far less detail than a similar exposure through the *Space Telescope*'s Wide Field/Planetary Camera (right). The "wormlike" streaks in the photo are produced by cosmic rays striking the camera's CCD detector.



vations would fill an encyclopedia.

Data from the telescope is relayed though one of two orbiting Tracking and Data Relay Satellites to a ground station at White Sands, New Mexico. The data is then relayed to Goddard Space Flight Center, where the ground control system must ensure that the information isn't lost or corrupted in any way. The quality of the data can be hurt by data gaps, bit error rates, and telemetry dropouts. Next, most of the engineering data relating to spacecraft systems is analyzed at Goddard, while science data is sent to STScI. Engineering data relating to the instruments' operation is also sent along to help diagnose any observation problems.

STScI processes the flood of data automatically using a computer pipeline called the Post Observation Data Analysis System. The data first need to be calibrated into scientifically meaningful units: wavelength, magnitude, flux, etc. Second, calibration removes the signature characteristic of a specific instrument. An astronomer needs to know what elements of his observation are real and what are errors or artifacts introduced by the instruments themselves. The data analysis system also saves the "raw" data before any processing is done to it in the event an observer needs to compare the original data with the calibrated data.

A guest observer at STScI can study his data at any of several workstations that provide image and graphics displays and send data to a film writer for photographic prints. Or, an astronomer can remain at his home institution and receive a magnetic tape containing the raw and calibrated data, as well as a package of interactive image processing and analysis routines developed at STScI.

Although individual astronomers interpret the telescope's observations, astronomy as a whole benefits from the *Space Telescope*. The telescope's unique capabilities allow astronomers to investigate quasars and active galactic nuclei, the cosmological distance scale, circumstellar disks, the structure and evolution of young galaxies, and other topics at the frontiers of astronomy. By doing so, the *Hubble Space Telescope* promises to make fundamental scientific breakthroughs that could revolutionize our current understanding of the universe. ☐

Ray Villard is public information officer at the Space Telescope Science Institute in Baltimore, Maryland.

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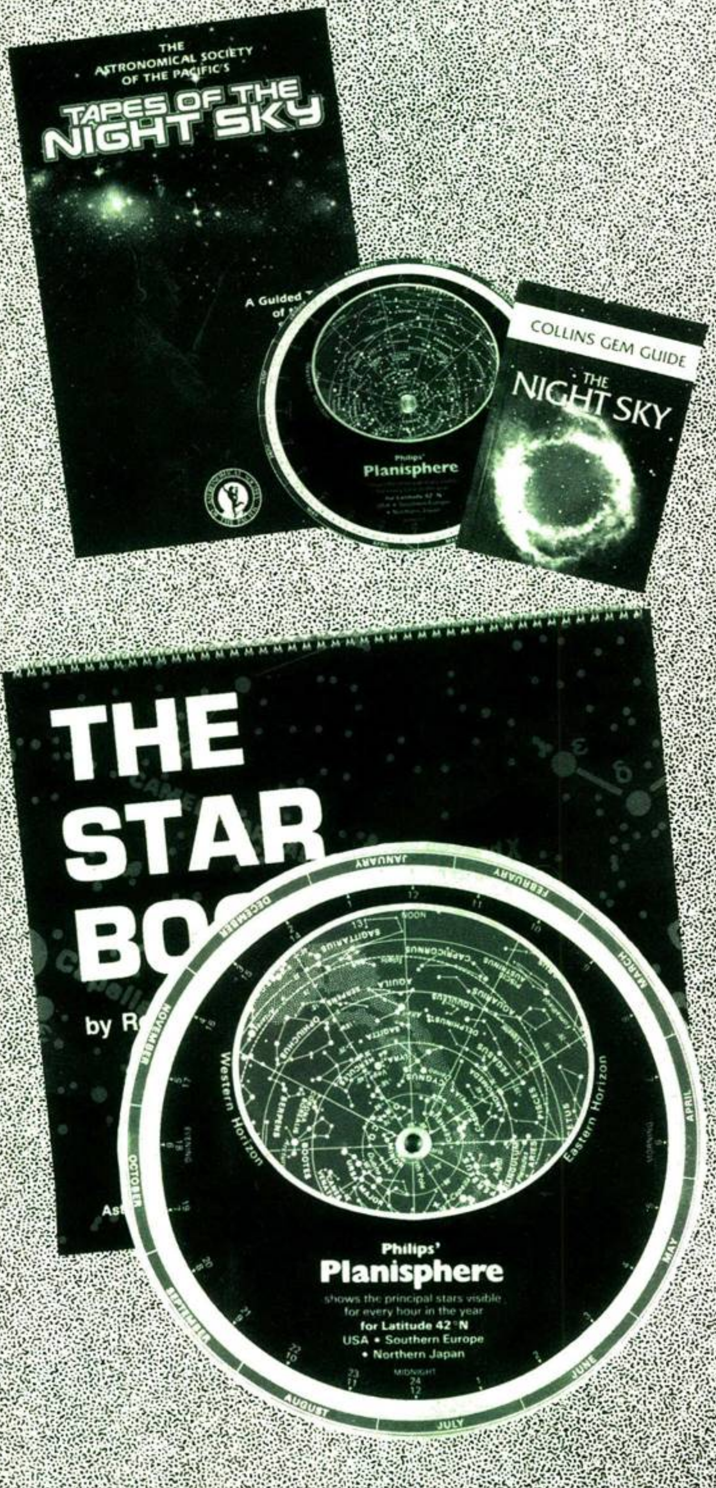
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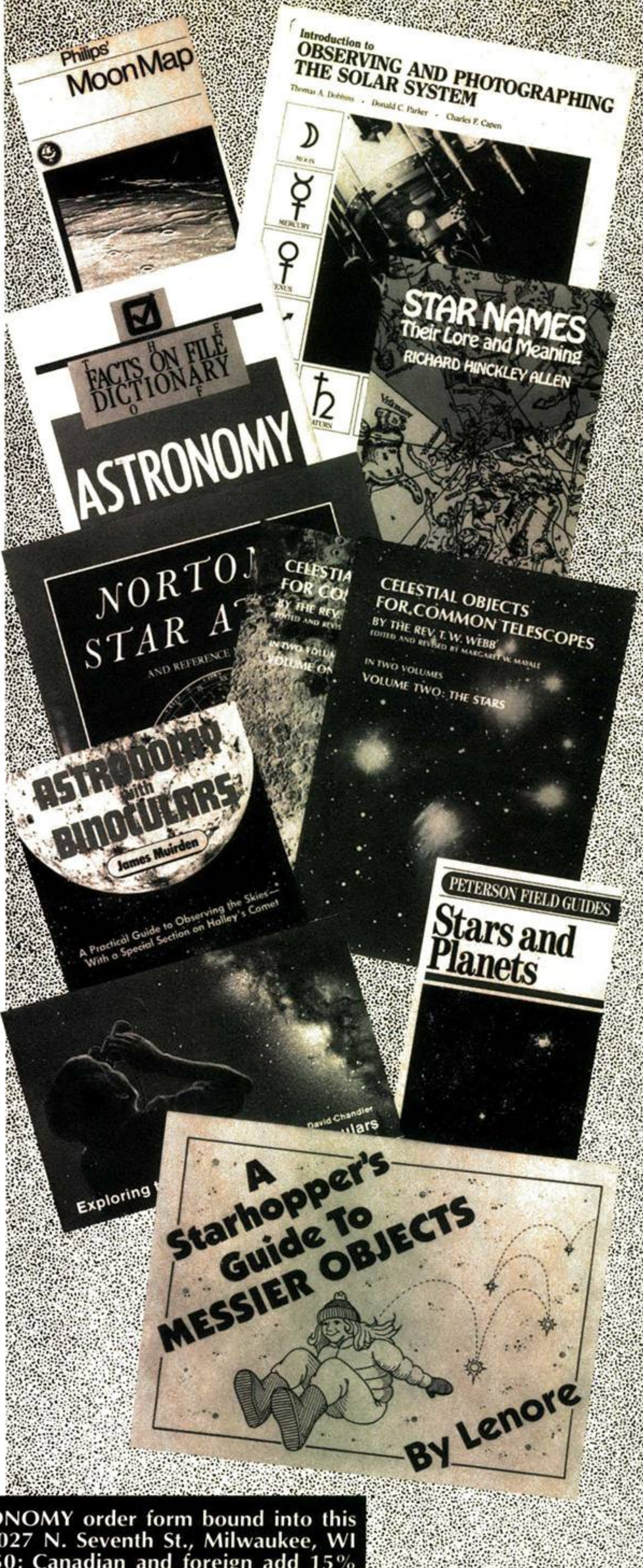
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COSMOLOGY

How Far to the Galaxies?

Astronomers are closing in on a reliable method for measuring the distances to the nearest galaxies.

by Vincent Kiernan

How far away are the galaxies? The question instinctively springs to mind when we gaze at these wispy objects in a telescope. Unfortunately, the answer is far from simple. Although distances to the nearest stars are known to within an accuracy of about 3 percent, once we venture toward the nearest galaxies accuracy decreases very quickly, to as much as 20 percent. By the time we reach the Virgo Cluster of galaxies, that value is closer to 50 percent.

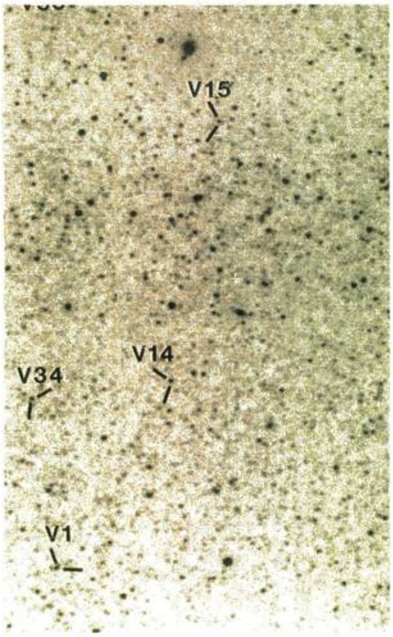
Astronomers want to measure these distances with greater precision. It is an enormous task made more difficult because the universe is so complex. If all stars and galaxies had the same true brightness, determining their distances would be much like judging the distances of cars on a desert highway at night by the brightness of their headlights (assuming, of course, that all car headlights are equally bright). Cars with dim headlights would lie at a greater distance than cars with bright headlights.

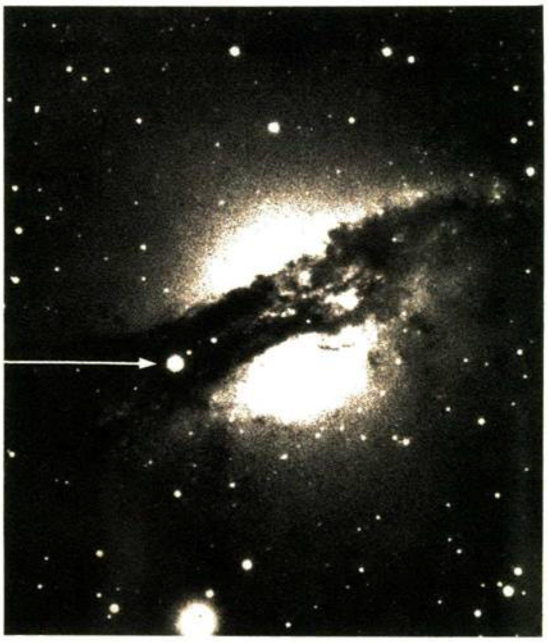
But just as car headlights in reality are not all equally bright, so it is with stars and galaxies in the universe. The solution to ascertaining cosmic distances accurately is to find an object with an absolute luminosity that is known without question. The distance to that object can then be inferred by comparing its apparent brightness with its true brightness. Such objects, the mileposts in the distance scale, are called standard candles.

The problem, however, is that no single standard candle has been able to solve the distance scale problem. Physical conditions in the universe, such as intervening dust, and the vast distances involved affect how bright a standard candle appears to us in unpredictable ways. For example, the true brightness of certain variable stars found mainly in the arms of spiral galaxies are dampened by dust but no one is sure by how much. And although some variable stars are useful as standard candles in nearby galaxies, they are too dim to be resolved in more distant galaxies.

So the strategy, begun by Edwin Hubble in the 1920s and painstakingly refined by others since, has been to construct a "ladder" of distance indicators, objects whose true brightnesses can be found despite the physical factors that affect their brightness, and to extend it farther and farther into the universe.

The climb up the distance ladder usually begins by nailing down the absolute brightnesses of certain stars in the Sun's stellar neighborhood. Then, when objects similar to these stars are pinpointed in a nearby galaxy, their apparent brightnesses can be used to estimate that galaxy's distance. The primary "rungs" are Cepheid variable stars, a large class of luminous yellow giants that pulsate regularly in bright-

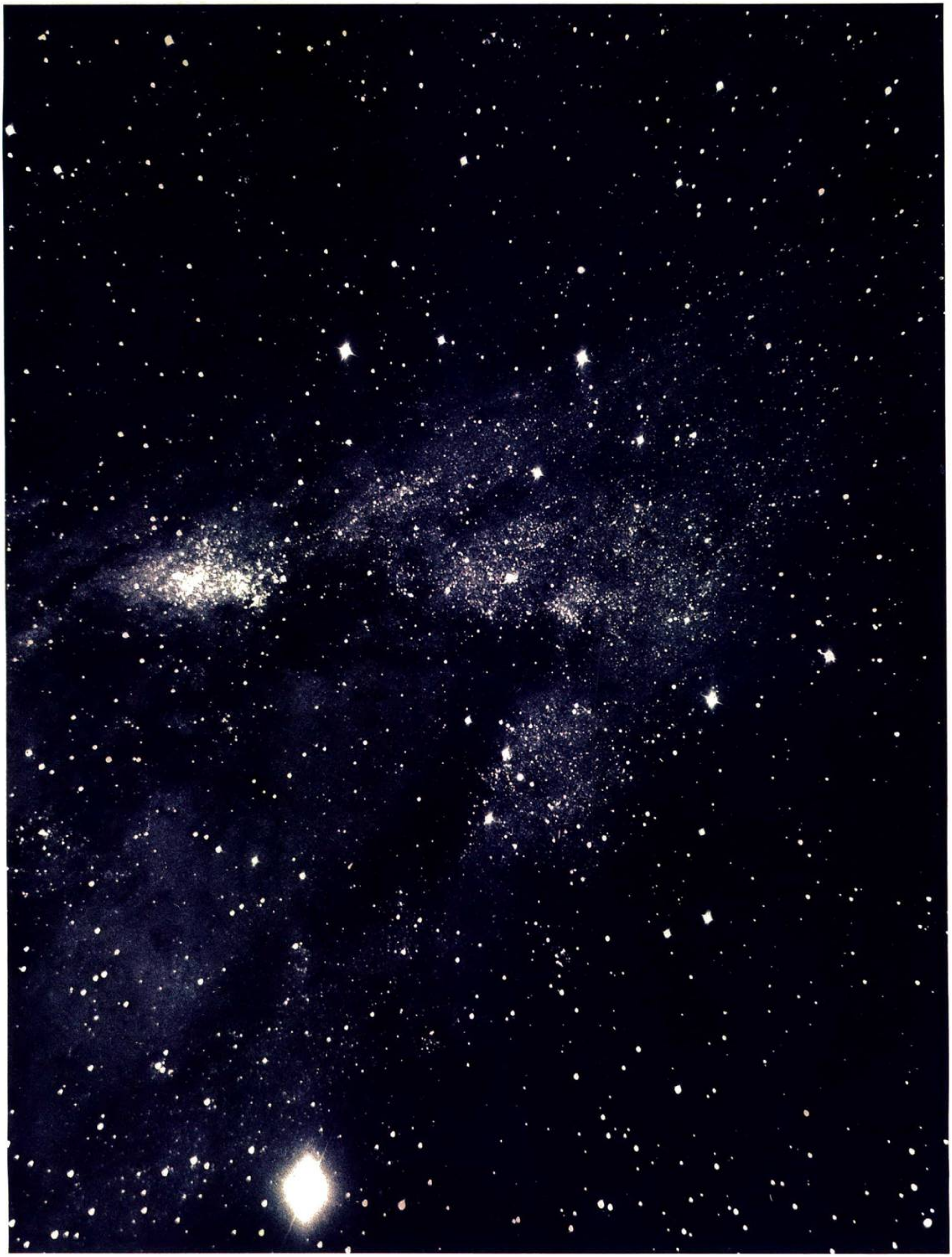




Stepping Stones into Space

Two distance indicators with very different distance ranges are Cepheid variable stars (far left) and supernovae (left). By comparing the absolute magnitudes of Cepheids in our Galaxy with those of Cepheids in neighboring galaxies, the distances to those galaxies can be derived. The Cepheids are members of the dwarf galaxy IC 1613. Cepheids located in the spiral arms of a more distant galaxy, M31 in Andromeda (opposite page), put its distance at about 2 million light-years.

Though they are very bright and can be seen in remote galaxies, supernovae occur rarely in any one galaxy; thus they aren't used as distance indicators as extensively as Cepheids. This supernova in the peculiar galaxy NGC 5128 was photographed in May 1986.



ness over periods ranging from one to seventy days. What is most remarkable about Cepheids, and what makes them one of the standard bearers of the distance scale, is that their absolute luminosities are directly related to the period of their brightness fluctuations: the brighter the Cepheid, the longer its period. Once absolute luminosity and distance were determined for the Milky Way Cepheids in 1917, the way was forged to estimate distances to galaxies close enough to contain observable Cepheids.

The Distance Scale Debate

Cosmic surveyors use at least twenty-seven distance indicators, including Cepheids. The diverse list includes globular clusters, planetary nebulae, supernovae, and galaxy diameters, to name a few. But there's a "small" catch: No distance indicator is 100 percent accurate, and the errors from using multiple indicators quickly multiply. Over the past fifty years, the thrust in extragalactic distance scale research has been to develop accurate methods of utilizing the strengths of various distance indicators while contending with their weaknesses.

Because astronomers don't always agree on assumptions about the universe, they naturally don't always agree on how to best utilize the distance indicators. As a result, a rift has arisen over which distance indicators to use and how to use them. What one group of astronomers sees as a precise choice in methodology, the other often considers to be imprecise.

One of the main players in the distance scale debate is Allan Sandage of The Observatories of the Carnegie Institution of Washington, in Pasadena, California (formerly Mount Wilson and Las Campanas Observatories). Since the early 1950s, Sandage has been correcting and refining Hubble's distance ladder. Sandage and his collaborator, Gustav Tammann of the Astronomical Institute at the University of Basel in Switzerland, have constructed a distance scale using what they judge to be the best distance indicators for various "reaches" into extragalactic space.

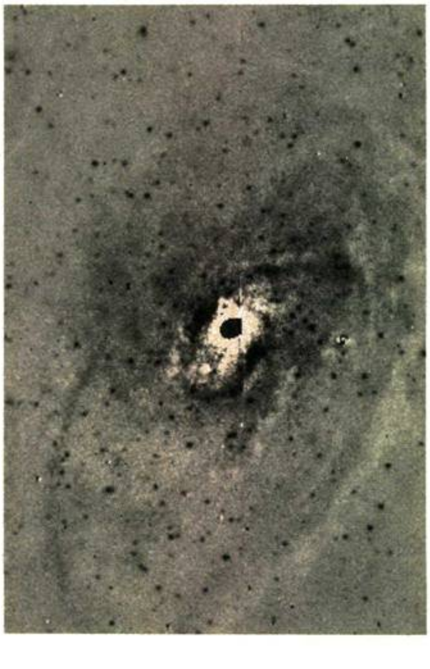
They begin by determining the distance to nearby galaxies using Cepheid variables. Beyond these galaxies, they use the absolute magnitudes of supergiant stars and the sizes of bright nebulae, assuming that the absolute magnitudes of the supergiants and the sizes of the nebulae are about the same as they are in our Galaxy. For the most distant galaxies, they calculate distances using Type I supernovae, the brightest of the two types of supernovae, or the brightest member of a galaxy cluster, assuming that its absolute magnitude is the same as the brightest members in other galaxy clusters.

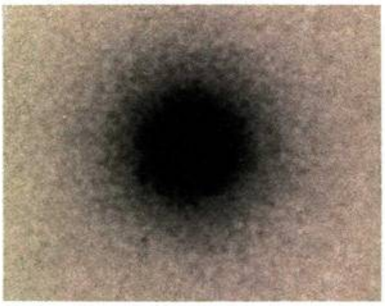
Gerard de Vaucouleurs of the University of Texas at Austin follows a very different path. At each step of the distance ladder, he uses a wide range of distance indicators and averages the results to compensate for errors in any one technique.

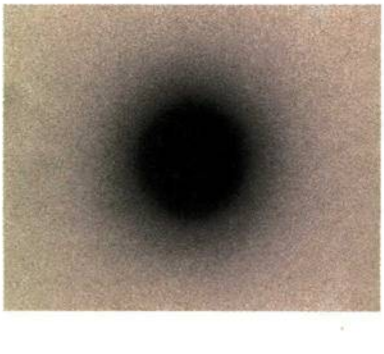
De Vaucouleurs begins by recalculating the distances of primary distance indicators of our Galaxy, such as novae and Cepheid variables, and comparing those distances with similar indicators in members of the Local Group of galaxies. Then de Vaucouleurs applies a class of secondary indicators in the Local Group (such as the brightest red giants, the brightest globular clusters, and the largest ionized nebulae) to determine the distances of galaxies out to almost 100 million light-years. Finally, he employs tertiary indicators in these galaxies, such as the diameters and total magnitudes of the galaxies themselves, to extend the distance ladder even farther.

The two distance scales are based on different premises about our Galaxy. Sandage and Tammann assume that there is relatively little dust to absorb the light of galaxies in the direction of the poles of our Galaxy. De Vaucouleurs, on the other hand, assumes that the solar system lies in a plane of dust and that there must be significant obscuration of extragalactic light coming through the poles.

These two approaches were put into proper perspective in a book published in 1985 called *The Cosmological Distance Ladder* by Michael Rowan-Robinson of Queen Mary College in London. Rowan-Robinson put in print what a growing number of astrophysicists apparently are now saying to each other: Neither side is right; the correct answer must lie somewhere in between. Rowan-Robinson wrote that de Vaucouleurs' "short scale" underestimated the distances to nearby galaxies, probably by overestimating the effect of dust and underestimating Cepheid brightnesses. Conversely, he concluded that Sandage and Tammann's "long scale" overestimated distances by underestimating the dampening effect of dust on stellar magnitudes and using inac-







Grasping at Stars

The Virgo galaxy cluster (opposite page) is too distant for telescopes to detect individual stars in galaxies. But with improved instrumentation, astronomers hope to establish the precise distance to this cluster.

New imaging techniques reveal planetary nebulae as black spots in the central region of galaxy M81 (far left). Planetary nebulae make good standard candles because the brightest ones don't exceed a certain magnitude.

The degree of "coarseness" in CCD images of galaxies also has the potential to measure extragalactic distances. A nearby galaxy (left, top) appears granular because its stars resolve into clumps within each pixel. The same galaxy at four times the distance (left, bottom) appears smoother because more stars make up each pixel.

curate visual estimations of the sizes of the cores and haloes of ionized hydrogen nebulae in spiral galaxies.

What's Constant and What's Not

The choice of the long or short distance scale has critical implications for cosmology because each implies a radically different size and age of the universe. The long scale applies to a universe in which galaxies have had time to recede to vast distances; the short scale applies to a smaller, younger universe.

Astronomers describe the size and age of the universe in terms of Hubble's law, which states that distant galaxies recede faster than nearby galaxies. Hubble's law is usually written as an equation in which a galaxy's recessional speed equals its distance times a constant of proportionality called the Hubble constant. Basically, the Hubble constant expresses the rate at which the universe is expanding at increasingly greater distances.

The beauty of this faster-is-farther relationship is that if the Hubble constant is known, the distance to any galaxy can be found simply by taking a galaxy's spectrum and measuring how far its spectral lines are shifted toward the red wavelengths. The higher the red shift, the faster the galaxy is receding, therefore, the farther away it must be.

Before this equation can be solved, a definitive value for the Hubble constant must first be derived from the distances established by standard candles. However, divergent assumptions about the absolute luminosities of standard candles result in varied distance estimates. Consequently, when different galaxy distances are compared with their red-shifted velocities, the result is an ambiguous value for the Hubble constant.

Standard Galactic Candles

The tiny specks near the center of this photo are members of the Hercules galaxy cluster. This cluster fits comfortably within one square degree of sky. The Virgo Cluster (see photo, page 50), which is approximately twelve times nearer, sprawls over 120 square degrees of sky. At distances of the Hercules Cluster (about 650 million light-years), the brightest galaxies in the cluster are used as standard candles. Rough distances are derived by comparing the absolute magnitudes of remote galaxies with nearer galaxies of similar type and luminosity whose distances have been determined by more direct methods. The Hercules Cluster is particularly suitable for determining the Hubble constant because it lies beyond the gravitational influence of the Virgo Cluster.

At great distances, the short-scale universe is exactly half the age (and thus half the size) of the long-scale universe. Sandage and Tammann's long scale yields a small value for the Hubble constant (about 50 kilometers per second per megaparsec), which translates into a relatively old age for the universe (20 billion years). By contrast, de Vaucouleurs' short scale yields a much larger value (about 100 kilometers per second per megaparsec), which translates into a younger age for the universe (10 billion years).

The age issue, however, is where de Vaucouleurs' work runs into trouble. For example, some stars in globular clusters are estimated to be between 14 and 20 billion years old — older than de Vaucouleurs' universe! One way out of this conflict is to invoke a force to counteract expansion. This force would, in effect, allow the universe to be both relatively old and relatively small.

Albert Einstein tacked just such a force, known as the "cosmological constant," on to his general theory of relativity even though his equations demanded an expanding universe, something neither Einstein nor astronomers at that time could imagine. But when Hubble revealed cosmic expansion by measuring the velocities of receding galaxies, the cosmological constant was voided by giving it a value of "zero" in Einstein's equations. Today, there is little support among theorists for the existence of a cosmological constant.

A Burgeoning Field

Despite their different methodologies, proponents of the long and short scales have the same goal: determine as accurately as possible cosmological distances. For many decades, this work was conducted by a handful of astronomers, said Paul Hodge, an astronomer at the University of Washington who studied under Sandage. "The field of the extragalactic distance scale since 1920 has been dominated by very, very small numbers of people, like one or two," he said. That situation developed because very few astronomers had sufficient access to large telescopes to make scientifically credible challenges. "For many years, it was only Hubble who did anything that people believed. When he died, Sandage took his place."

As large telescopes became more available, however, other astronomers started working in the field. "Now, with thirty or forty people working on the problem, it's a much healthier situation," Hodge said. Some of the newer researchers are trying to refine current distance indicators, while others are developing entirely new ones. Many hope that their work will help free the logjam over the distance scale once and for all.

Jeremy Mould of the California Institute of Technology is one of the new breed of astronomers working on the distance scale problem. Mould, John Huchra of the Harvard-Smithsonian Center for Astrophysics, and the late Marc Aaronson of the University of Arizona use the spiral galaxy's rotational velocity to determine its intrinsic brightness and thereby its distance. The technique, first proposed by R. Brent Tully and J. Richard Fisher in 1977, uses radio observations of neutral hydrogen at the 21-centimeter wavelength to derive a galaxy's rotation speed.

A galaxy's rotational speed is determined by the mass of the galaxy. If it is assumed that galaxies of equal mass produce equal light, then a galaxy's intrinsic brightness is related to its rotational velocity. Simply stated, "Galaxies that rotate fast have high intrinsic luminosities," said Mould. A comparison of the galaxy's absolute magnitude and its apparent magnitude then yields the distance.

As most distance-estimating methods go, the Tully-Fisher relation is fairly straightforward. Still, Mould and his colleagues have had trouble using it as a reliable distance indicator because they studied galaxies emitting mainly blue light, which is scattered by intergalactic dust. This required them to approach the problem from another direction. They focused on the galaxy's luminosity in near-infrared light, which is not affected much by dust. Their results tend to favor the short distance scale rather than the long one. Mould would like to use the *Hubble Space Telescope* and the "infrared Tully-Fisher relation" to determine distances to a variety of galaxies in the Virgo Cluster.

The Distance to Virgo

Many astronomers believe that reliably determining the distance to the Virgo Cluster, the nearest large galaxy cluster, is the key to the whole distance issue. If the distance to the Virgo Cluster can be calculated, researchers can more accurately extend the distance scale to farther galaxies.

Distance estimates for galaxies nearer than the Virgo cluster are complicated by the gravitational interplay between the Milky Way and nearby galaxies. This local gravity drag disrupts the otherwise smooth expansion of the universe and gives a "false reading" of the Hubble constant. Only at the distance of the Virgo Cluster and beyond, Mould said, do those perturbations smooth out enough to allow researchers to get a true measure of the universe's expansion. "If we could determine the distance to the Virgo Cluster most of the distance scale controversy would end," Mould said.

As it stands, the distance to the Virgo Cluster as determined by the long and short scales differs by a factor of about one-and-a-half times (this value is for a *nearby* cluster, which is why there is not a factor of two difference). Sandage and Tammann estimate the Virgo Cluster distance is about 71 million light-years, while de Vaucouleurs estimates 49 million light-years.

Another new approach, developed by George Jacoby and colleagues at Kitt Peak National Observatory, uses the brightest planetary nebulae in nearby galaxies as standard candles. (See AstroNews, December 1988.) One of the strengths of using planetary nebulae as distance indicators is their bright upper-magnitude cutoff. Of the more than two thousand planetaries surveyed in thirty galaxies so far, the brightest all have the same absolute magnitude, −4.4. This magnitude cutoff implies that the brightest planetaries have similar luminosities in all galaxies.

In many respects, planetary nebulae have great potential as standard candles. They appear in all types of galaxies (not just spirals), they are located in relatively dust-free regions of their host galaxies, and they require much less telescope time to measure their brightness than do, for example, Cepheid variables.

Cepheid variables, however, are still the distance indicator of choice, and may eventually be the means for finding the distance to the Virgo Cluster. The reasons for using Cepheids are many: they are intrinsically very bright, they are relatively abundant in nearby galaxies, their rapid rise in brightness makes them easy to distinguish from other variable stars, and astronomers understand the physics of their variability.

The main difficulties astronomers have had in estimating the true brightnesses of Cepheids (and, for that matter, most other distance indicators as well) have largely been due to dimming effects by interstellar dust and the inability to do photometry because of crowded stellar fields. Since the early 1980s, however, detailed photometry of Cepheids by Wendy L. Freedman of the Carnegie Observatories has circumvented these problems somewhat. Recent improvements in software and detector technology have allowed her to measure the brightness of a Cepheid separately from its neighboring stars, obtain precise measurements over a star's whole range of brightness, and observe many wavelength bands to correct for dimming by interstellar dust. Her work has helped astrophysicists deepen their understanding of the period-luminosity relationship.

Major Distance Indicators

Object	Approximate Limit (light-years)
Red Giants	3 million
Cepheids	23 million
Supergiants	32 million
Planetary Nebulae	46 million
Novae	65 million
Tully-Fisher	81 million
H II Diameters	81 million
Supernovae	650 million
Brightest Galaxy in Cluster	1.5 billion

Although Cepheids generally aren't bright enough to be spotted by ground-based telescopes in galaxies more than about 26 million light-years distant, the *Hubble Space Telescope* should be able to detect Cepheids out to the Virgo Cluster. Many astronomers believe that these observations will not only firmly establish the cluster's distance, but will also serve as a criterion for other distance indicators.

New Techniques

Some researchers think that to reduce the uncertainties bedeviling the field, the entire distance ladder needs to be replaced with a one-step measurement. John Tonry thinks he may have the solution.

Tonry, a physicist at the Massachusetts Institute of Technology, takes advantage of a peculiarity in the images of galaxies taken by charge-coupled devices (CCDs), the sensitive cameras that have all but replaced conventional photography in modern astronomy. Because of their proximity, it is easier to resolve nearby galaxies into stars than more distant galaxies, therefore, CCD images of nearby galaxies look coarse, while images of more distant galaxies look smooth. Tonry reasoned that the degree of coarseness or smoothness of a galaxy's image in a CCD display is inversely proportional to the galaxy's distance.

It is misleading, however, to say that individual stars are captured in the images, Tonry explained. Rather, a "statistical clump" of bright stars on a background of fainter stars is recorded in each CCD picture element, or pixel. For example, a single pixel in a nearby galaxy may show a clump of fifteen giant stars on top of an overall background of twenty stars in the same area of the galaxy, resulting in a coarse image. A more distant galaxy, meanwhile, may contain about seventy giant stars on top of an average of five hundred or so stars; the greater number of stars per pixel translates into a smoother image.

Tonry's technique must compensate for other factors that can affect an image, such as the presence of bright globular clusters or faint background galaxies. But once these are subtracted from the image, what remains are ordinary giant stars, which astrophysicists understand reasonably well.

Preliminary tests of his pixel method with various galaxies have been encouraging, and Tonry hopes to validate the technique later this year. "What I'm hurting for now is data," he said. But he's not hurting for self-confidence. "Personally, I think this is the benchmark around which people are going to compare their various techniques," he predicted.

As the astronomers go about their work, they might do well to remember an insight by sixteenth-century British poet Edmund Spenser. Writing about the conflict between finding God and adhering to organized religion, Spenser penned: "He that strives to touch the stars, oft stumbles at a straw."

Four centuries later, astronomers striving not to touch the stars but distant galaxies are encountering many straws on which to stumble as they make their way up the cosmic distance ladder. Considering the unknowns involved, controversy is a natural and wholesome outcome. The raucous discussions often overheard at scientific symposiums and meetings on the extragalactic distance scale do not represent the babble of confusion as much as the dialogue of construction. Today, astronomers are haggling over finer and finer issues, and the permissible deviations in values like the Hubble constant are gradually being narrowed. The *Space Telescope* also promises to pin down the distance to the Virgo Cluster, not to mention clinch some loosely held ideas about the age of the universe. Upon these foundations, astronomers will fashion the next rungs to the galaxies. Eventually, we will get there; perhaps sooner than we think. ☐

Vincent Kiernan is a Knight Science Journalism fellow at the Massachusetts Institute of Technology.

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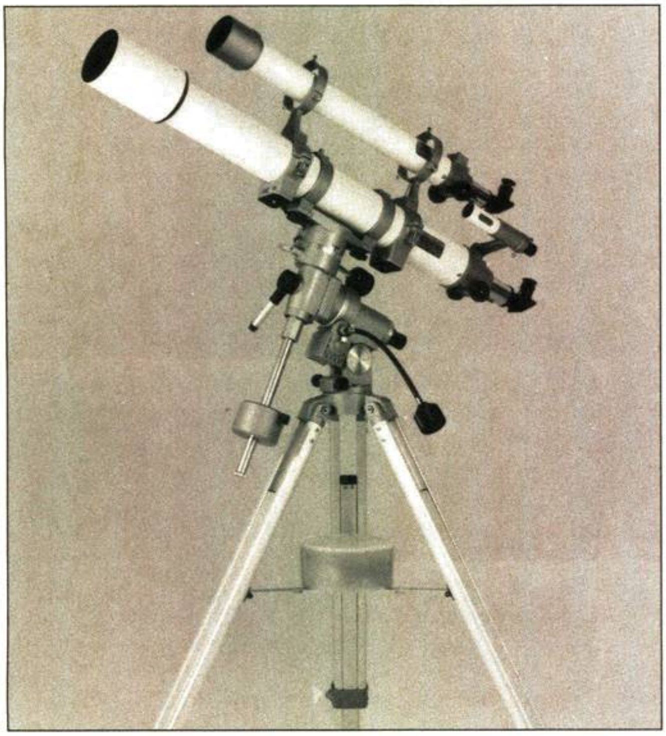

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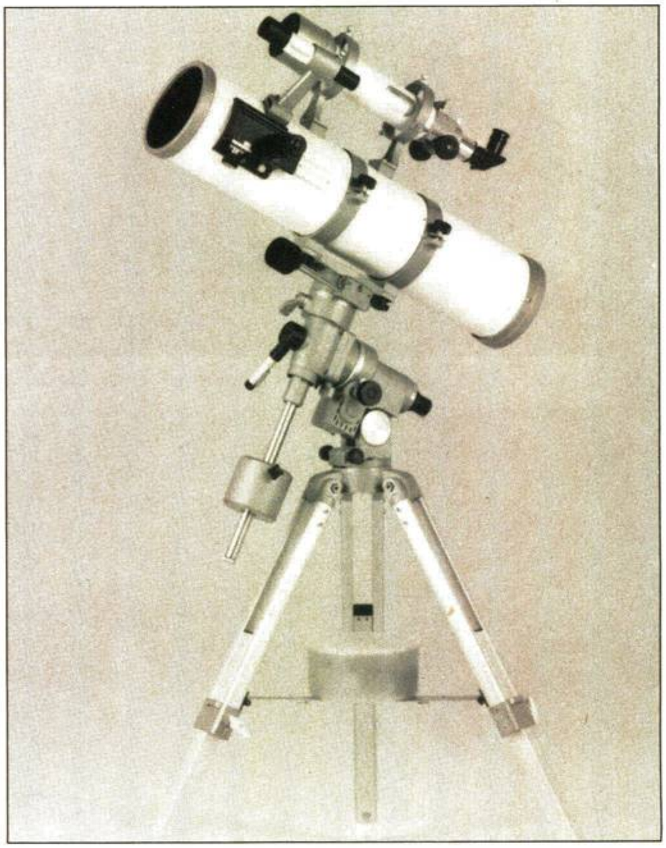

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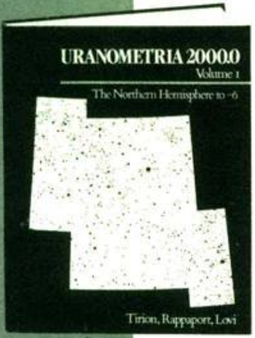

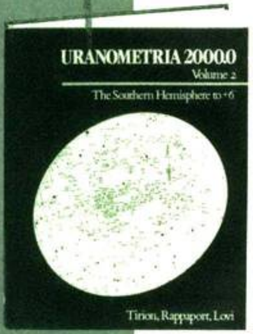

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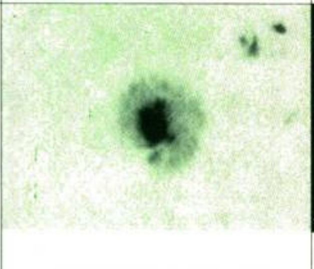

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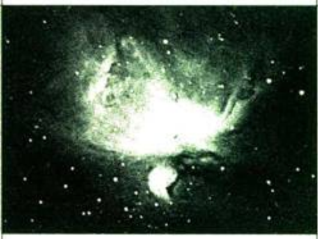

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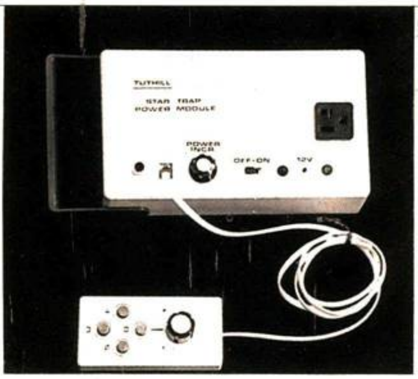

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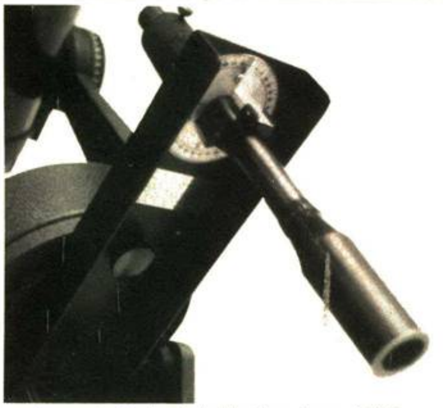

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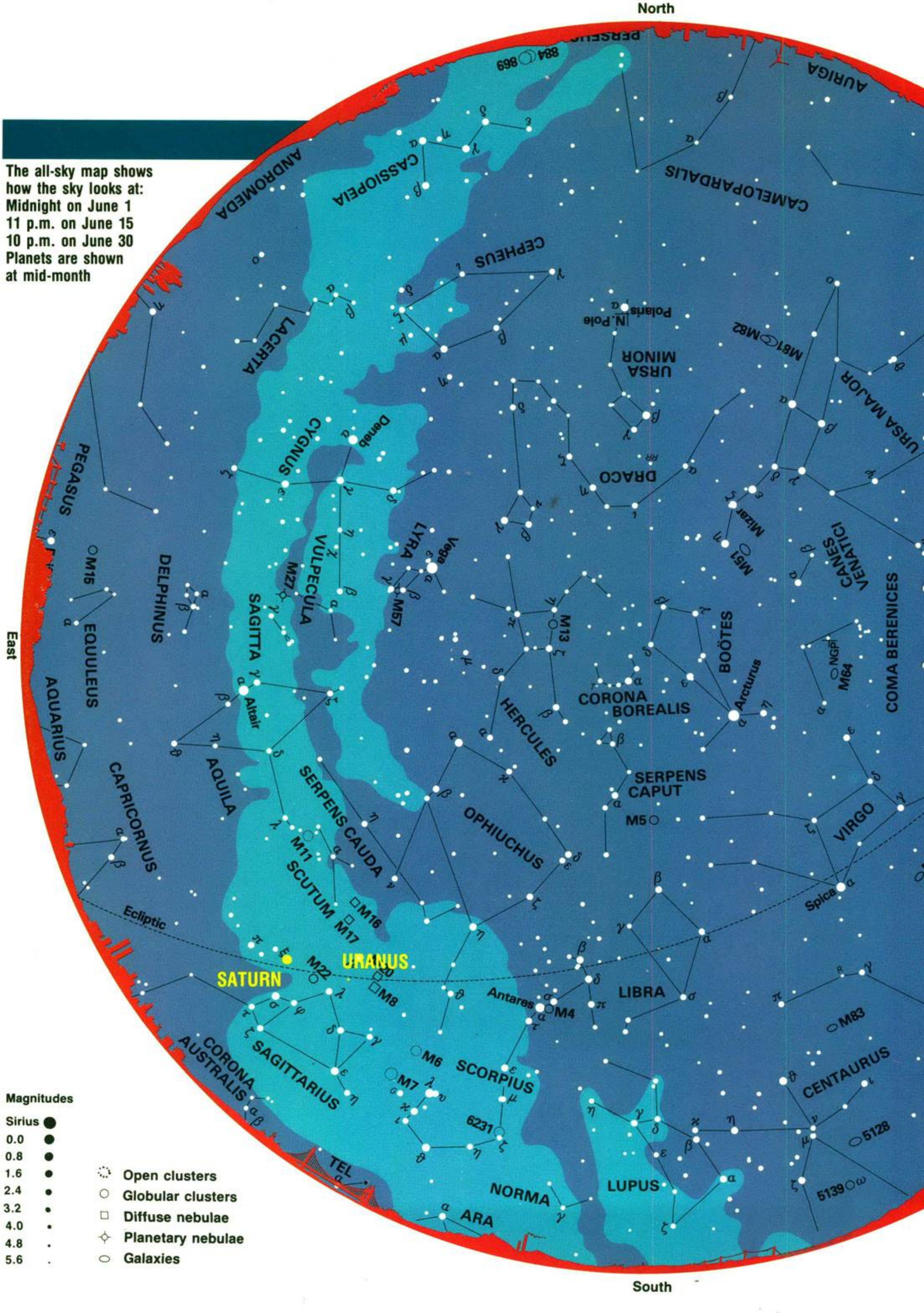
The all-sky map shows how the sky looks at:
Midnight on June 1
11 p.m. on June 15
10 p.m. on June 30
Planets are shown at mid-month


North
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URSA MAJOR
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CYGNUS
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M27
LYRA
Vega
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M51
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DELPHINUS
M15
EQUULEUS
SAGITTA
M13
HERCULES
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NGP
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Arcturus
CORONA BOREALIS
AQUARIUS
Altair
AQUILA
CAPRICORNUS
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SCUTUM
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Antares
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SAGITTARIUS
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Magnitudes
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Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

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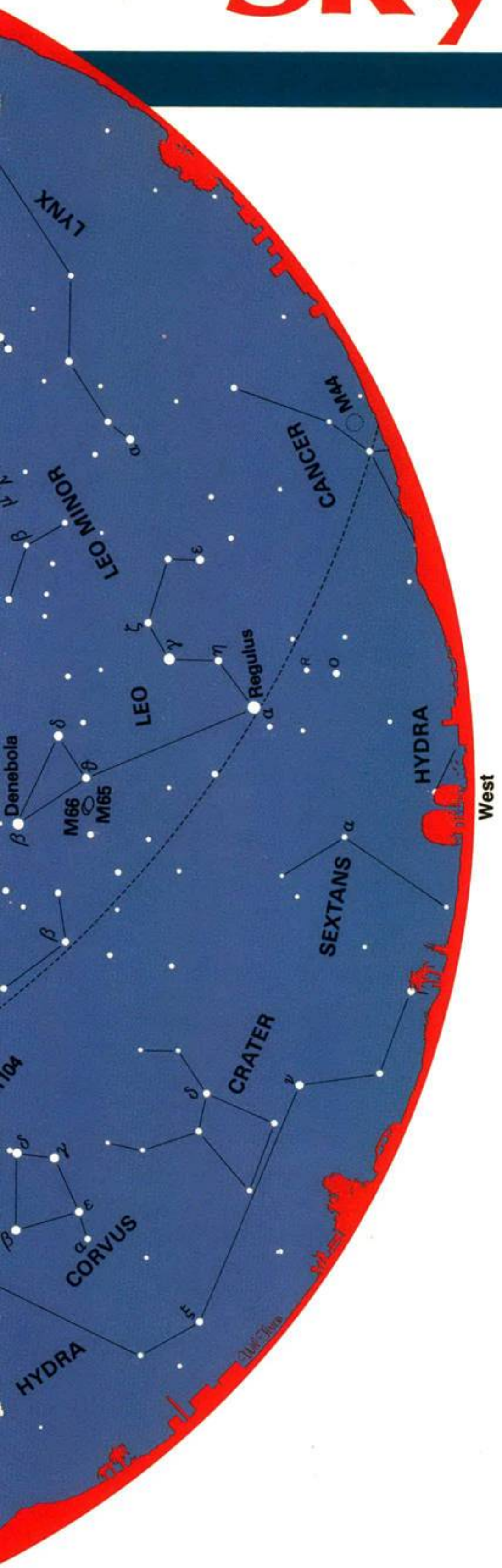
JUNE 1989



SATURN JOINS NEPTUNE — AGAIN

Saturn passes just 18′ south of Neptune on the night of June 23/24. The two planets can be seen in the same telescopic field of view for a couple of weeks before and after this date.

MARS PASSES THROUGH THE BEEHIVE

The Red Planet passes through the center of the Beehive Cluster on the evening of June 27. Use binoculars or a low-power telescope to get the best view of the event.

TWO PLANETS MEET THE TWINS

Mars forms a straight line with the bright "twin" stars of Gemini, Castor and Pollux, on the evening of June 12. Two weeks later, after Mars has moved on, Venus lines up with the two stars.

Dates and Times

1 The Moon is at perigee (226,420 miles from Earth), 1:19 a.m. EDT

3 New Moon is at 3:53 p.m. EDT

4 The Moon passes 3° north of Venus, 9 p.m. EDT

5 Hygiea is at opposition

6 The Moon passes 1.6° north of Mars, 2 p.m. EDT
Mars passes 5° south of Pollux, 8 p.m. EDT

9 Jupiter is in conjunction with the Sun
The Moon passes 0.7° south of Regulus, 10 a.m. EDT

11 First Quarter Moon is at 2:59 a.m. EDT

12 The Moon is at apogee (251,321 miles from Earth), 10:24 p.m. EDT

17 The Moon passes 0.4° south of Antares, 5 p.m. EDT

18 Mercury is at greatest western elongation (23°)

19 Full Moon is at 2:57 a.m. EDT

20 The Moon passes 4° south of Saturn, 3 a.m. EDT

21 Summer solstice is at 5:53 a.m. EDT

23 Mercury passes 3° north of Aldebaran, 9 a.m. EDT

24 Venus passes 5° south of Pollux, 5 a.m. EDT
Saturn passes 0.3° south of Neptune, noon EDT
Uranus is at opposition

25 Vesta is at opposition

26 Last Quarter Moon is at 5:09 a.m. EDT

28 The Moon is at perigee, (229,261 miles from Earth), 12:25 a.m. EDT

Eye on the Sky by Deborah Byrd

THE QUADRUPLETS OF GEMINI

Venus returns to prominence in June, climbing above bright twilight for the first time since January. As it does so it joins Mars in a dance with the bright stars Castor and Pollux in the constellation Gemini.

The two planets and two bright stars can be found in the west-northwest as soon as the sky gets reasonably dark. Venus, though close to the horizon as June begins, climbs rapidly as the month progresses. It is by far the brightest of the four objects. Mars appears higher in the west-northwest but shines more than five magnitudes — a factor of one hundred — fainter than Venus. In fact, Mars is now dimmer than Castor and Pollux and would be inconspicuous if it was not so near the two stars.

Mars passes 5° south of Pollux on the evening of June 6, but it appears in a line with the two stars on June 12. Venus slides 5° south of Pollux on the night of June 23/24 and, as in the case of Mars, you will have to wait a few days to see Venus as a Gemini "triplet."

Although both planets are moving rapidly relative to the background stars, Venus is noticeably the faster of the two. Next month Venus catches up to Mars and passes half a degree from the Red Planet.

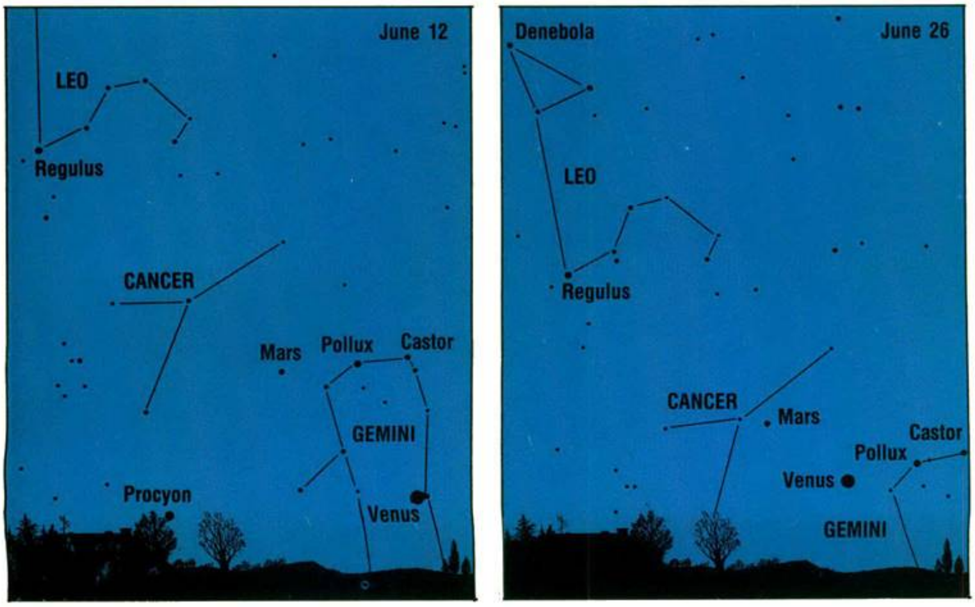
CATCH A GLIMPSE OF URANUS

In theory, it's possible to spot Uranus with the naked eye. In practice, however, objects as faint as the seventh planet are difficult to see unless you know exactly where to look.

Under ideal conditions, a person with average eyesight can see objects shining at 6th magnitude. Uranus shines at its brightest this month, reaching a magnitude of 5.6. What's more, because Uranus comes to opposition on June 24, the planet appears in the sky all night toward the end of the month. These two factors make June the best month this year to glimpse Uranus with the naked eye.

Uranus lies near the top of the "Teapot" asterism in Sagittarius. Because this is the most star-cluttered region of the Milky Way, you may want to find the planet first with binoculars. Start at Saturn (the much brighter object near Uranus) then scan about 8° west and 1° south. (The map at the top of page 61 will help you zero in on Uranus.)

After finding the correct region, you should be able to identify Uranus from its precise position and perhaps by its faint greenish tinge. Once you spot the planet, set the binoculars aside and try to glimpse Uranus with your eye alone. Averted vision, looking slightly off to one side instead of directly at an object to utilize the more light-sensitive area of your retina, may help.



MARS AND VENUS pass the bright stars Castor and Pollux this month. Look for Mars in line with the stars about forty-five minutes after sunset on June 12. Venus lines up with the pair in the early evening of June 26.

HIGH SUN, LOW MOON

The solstice occurs on June 21 at 5:53 a.m. EDT. The solstice is the moment when the Sun reaches its most northerly point on the dome of Earth's sky. It is a hallmark of the seasons, and marks the official beginning of summer in the Northern Hemisphere. On this day, notice how short the noontime shadows are and how long the Sun takes to move across the sky.

There is one aspect of the beginning of summer that you can observe at night. Watch for the Full Moon on the night of June 18/19. Because the Moon appears fully lit when it is in the opposite direction from the Sun and the

Sun swings high across the sky around the time of the June solstice as seen from the Northern Hemisphere, the June Full Moon executes a low arc across the sky. In fact, this month's Full Moon follows a path similar to the Sun's path on the first day of winter, only the Moon appears about 5° farther south in the sky because its orbit is tilted relative to Earth's orbit around the Sun.

Although the solstice marks the longest day of the year and the highest Sun, the hottest weather still lies some weeks ahead. This effect is called the "lag of the seasons," which occurs because the land and, in particular, the oceans take time to warm up from the cold of winter.

JUNE'S PLANETS

Venus creeps back into the evening sky this month but is destined to remain low in the west after sunset all summer. Still, Venus is so bright at magnitude −3.9 that you can see it even when it is low in the sky.

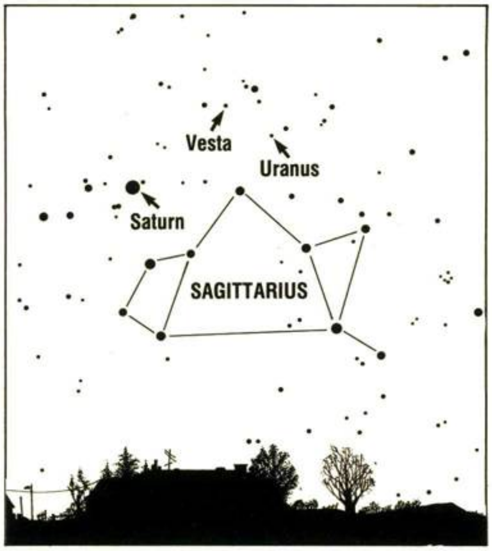
As you gaze at Venus, remember that it has recently emerged from behind the Sun, which makes this a good time to envision Earth, Venus, and the Sun in space. Try to picture Venus, which is now far across the solar system from Earth, racing along in its inward orbit around the Sun. Over the next several months, this rapid motion will carry Venus around to our side of the solar system. As you watch Venus low in the twilight sky and think of the Sun that recently set below the horizon, remind yourself that your world is also moving in its own vast orbit around the Sun.

Mars is visible above Venus in the west-northwest, although it is hardly recognizable as the fiery bright world we saw in our sky last fall. Mars shines at magnitude 1.8 this month. It is still moving rapidly toward the east among the stars; it begins the month near Castor and Pollux in Gemini and lies in Cancer by month's end. There Mars sweeps through the center of the Beehive Star Cluster on the evening of June 27. The Beehive is visible to the naked eye as a dim hazy patch under a very dark sky, but you'll get a better view of this event if you use binoculars.

Saturn is quickly approaching its early July opposition, when it will be opposite the Sun as seen from Earth. The golden-colored planet remains in Sagittarius in the approximate direction to the center of our Galaxy. Saturn shines brightly at magnitude 0.1, serene against the glittering backdrop of the Milky Way.

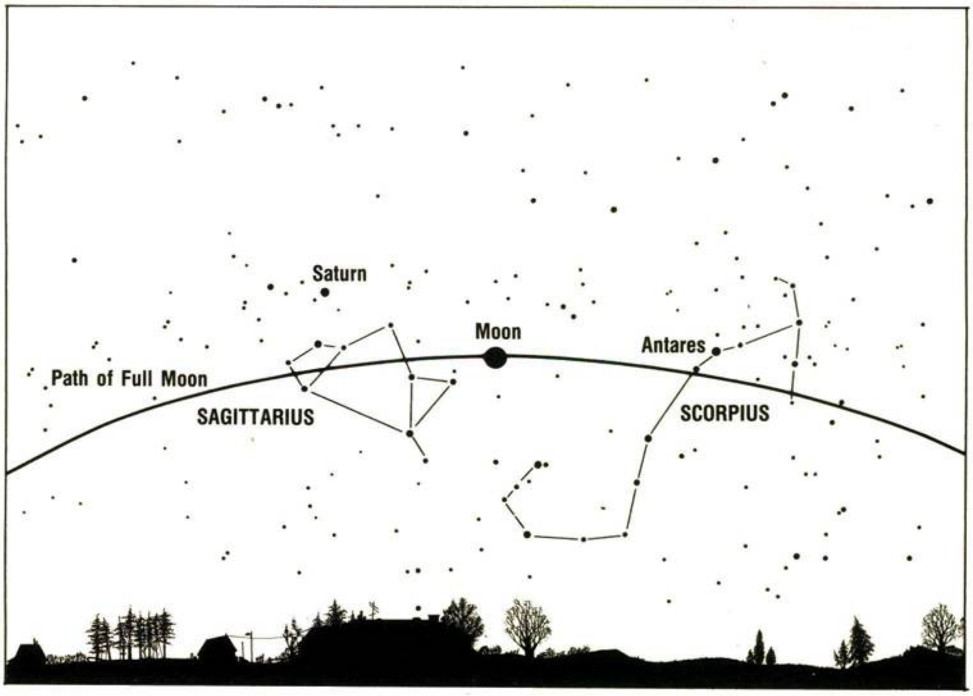
Early in the month, Saturn rises about an hour after the end of evening twilight, but this is still rather late in the evening if you are on daylight-saving time. Still, Saturn is now nearly at its most conspicuous for the year. It will be visible earlier in the evening later this summer.

Innermost Mercury pops into view in the morning sky in late June. The planet reaches greatest western elongation on June 18, although you have a better chance of seeing it in the week or so after that. It shines at magnitude 0.6 at greatest elongation and brightens to magnitude −0.6 by July 1. On the morning of June 23, watch Mercury slide 3° north of the reddish star Aldebaran. Although this apparition is not as good as the evening apparition that occurred in late April and early May, you should have little trouble spotting



URANUS APPEARS BRIGHTEST when it reaches opposition on June 24/25. Search for the naked-eye planet in the southeast above the Teapot asterism in Sagittarius around 11 p.m. daylight time in late June.

JUNE'S FULL MOON tracks lower across the southern sky than any other Full Moon for Northern Hemisphere observers. This year the Full Moon on June 18/19 won't climb higher than 25° as seen from the central United States.



Mercury in the morning twilight.

Jupiter cannot be seen until late this month because it is traveling behind the Sun as seen from Earth. It is most directly behind the Sun on June 9, when it rises at sunrise and crosses the sky with the Sun during the day. Look for Jupiter on the morning of July 2, when it passes within 1° of Mercury. The pair will be low in the morning sky at that time, so you may want to use binoculars to see them clearly.

JUNE'S STARRY SKY

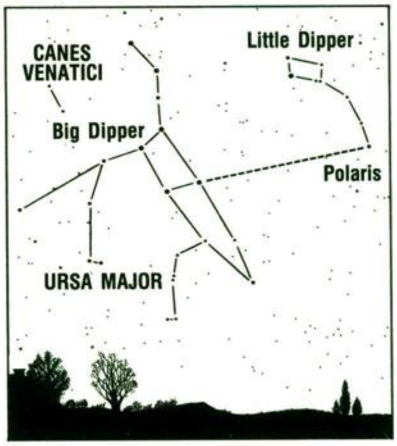
The most famous star pattern visible from the Northern Hemisphere is the Big Dipper. You can easily see it any evening in June, riding high in the northwest.

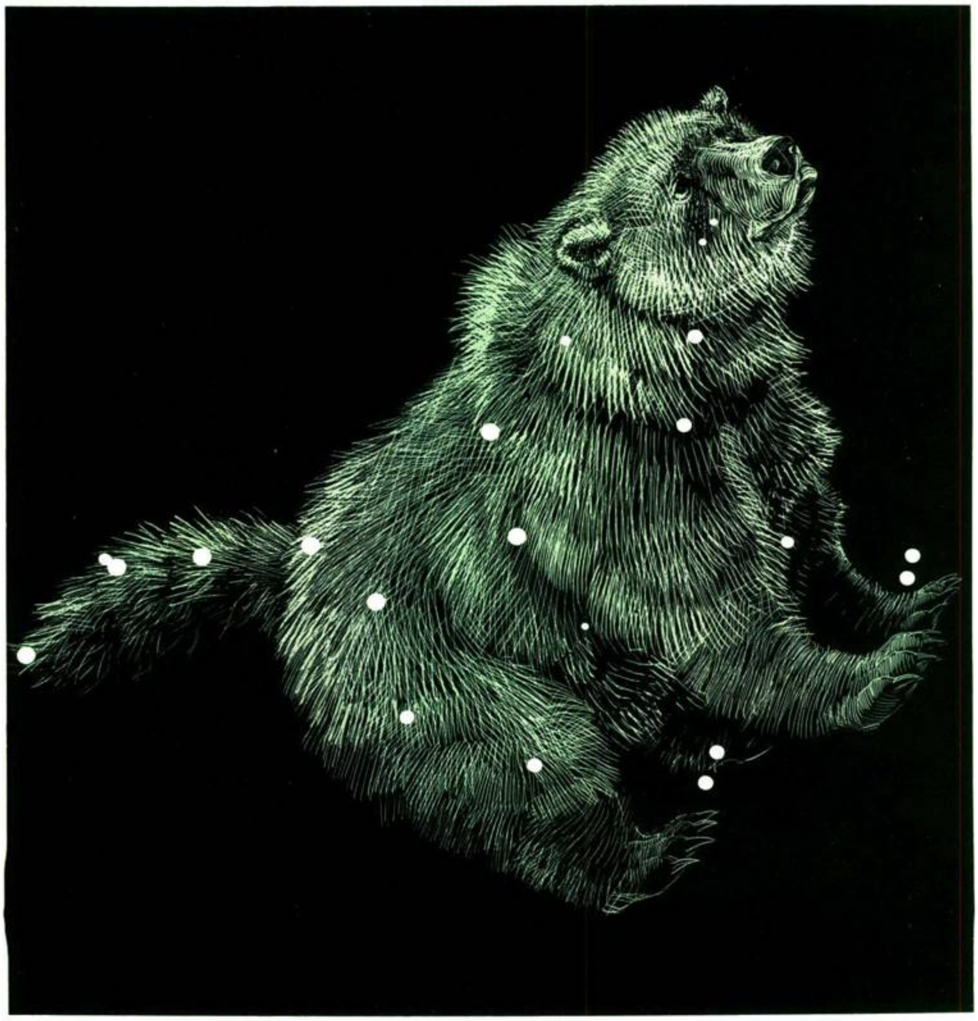
The Dipper consists of seven bright stars, four in the bowl and three in the handle. North of about 40° north latitude it is circumpolar. That is, it never sets below the horizon but instead circles endlessly around Polaris, the north star.

The Big Dipper, in fact, can lead you to Polaris. Simply draw an imaginary line between the two outer stars in the Dipper's bowl — from the bottom toward the top of the bowl — and extend this line about five-and-a-half times. This takes you to Polaris, the star around which the entire celestial sphere appears to turn.

Some people are surprised when they see that Polaris is not spectacularly bright, but it is the brightest star in an otherwise empty region of the sky. Though you may not notice at first, Polaris marks the end of the handle of the Little Dipper. The Little Dipper is almost as famous as its larger counterpart, but its stars are not as bright. Also, its shape is less like a true dipper.

THE BIG DIPPER appears high in the northwest late on June evenings. This famous star pattern, which points the way to the north star Polaris, is part of the constellation Ursa Major, the Great Bear.





Neither the Big nor the Little Dipper is a true constellation. Both are asterisms, noticeable patterns of stars within constellations. The Big Dipper belongs to the constellation Ursa Major, the Great Bear, while the Little Dipper is part of Ursa Minor, the Little Bear.

In the Greek myths, the Great Bear is Callisto. She was once a beautiful woman but was transformed into a bear by Hera, the jealous wife of Zeus, the king of the gods.

As Callisto wandered the forest, she is said to have met her son, Arcas. She raised up on her hind legs to embrace the boy, but he saw only a bear and shot and killed her. Zeus then took pity on them both and instantly changed Arcas into a bear also. He seized them by their tails and flung both bears into the sky. That is why, according to skylore, the bears both have long tails.

Yet Hera was still unhappy. She caused the gods of the ocean to forbid the bears to enter their waters. That is why, according to the myths, we see them above the horizon at all times, circling endlessly around the pole. □

Through the Eyepiece by Rick Shaffer

SATURN AND NEPTUNE IN THE SAME FIELD: ACT TWO

This month's leading event is a close conjunction between Saturn and Neptune. The two planets are only 18′ apart on June 24 and remain within 1° of each other for about three weeks before and after that date. Saturn and Neptune undergo three conjunctions this year, but this is the best of the three because both planets are only eight days away from opposition and are thus in the sky almost all night.

With the nearby, bright planet Saturn acting as a guide, Neptune is much easier to find this year than at any other time in the recent past. The close passage also gives telescopic observers the rare chance to compare the two planets in the same eyepiece field.

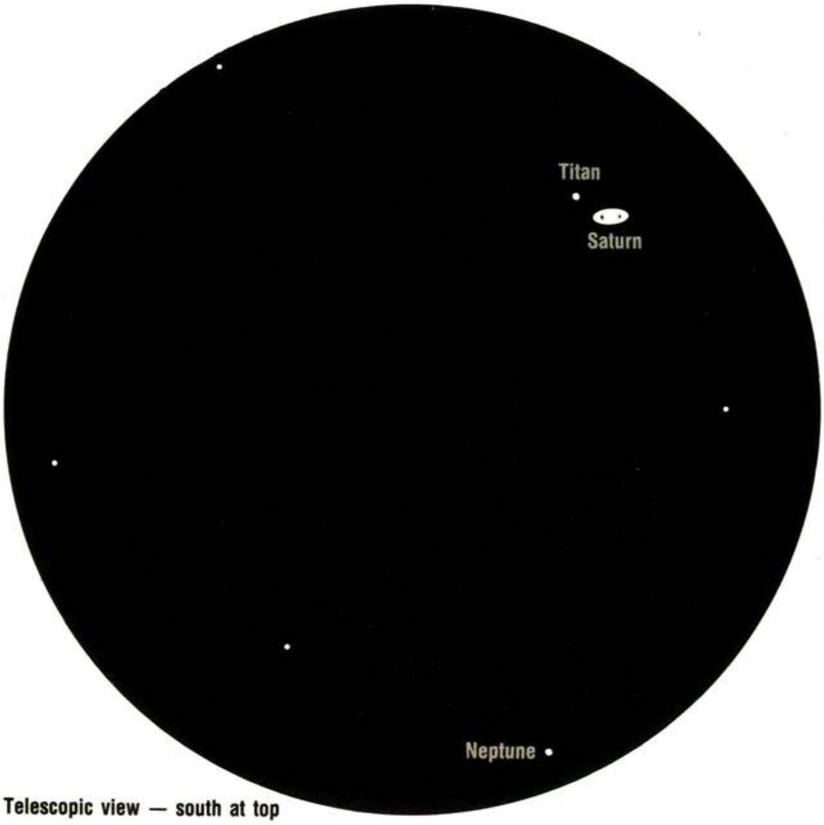
Begin observing Saturn and Neptune with a low-power eyepiece. If you own a 6-inch Newtonian or an 8-inch f/10 Schmidt-Cassegrain, start with a magnification between 30x and 50x. These powers are much too low for viewing any detail on the planets, but they will make the planets' colors appear as vivid as possible. Although the color of Saturn's 0.1-magnitude disk will remain vivid under quite high powers, Neptune's 7.9-magnitude disk will appear pale and washed-out as the power is increased. (I've found that viewing a planet first at low powers seems to allow my eye to retain at least a hint of the planet's color when viewing at higher powers.) The cream-to-tan color of Saturn's features should contrast nicely with the blue-gray color of Neptune's disk.

To see any planetary detail, you'll need to use higher magnifications. Saturn should show a wealth of detail under good seeing conditions. Its 18.3″-diameter disk displays several dusky bands in 6-inch and larger telescopes. In smaller telescopes, or when the seeing is poor, you may see only one or two of the bands. These atmospheric bands are much more subtle than the bands in Jupiter's atmosphere, and it may take several minutes of observing before you can see them clearly.

The showpiece of the solar system, Saturn's rings, span 42″ this month and are tilted about 25° to our line of sight. Look for the prominent Cassini division, which separates the outer A ring from the brighter, middle B ring. Under exceptional conditions you may also spot the thinner Encke division near the outer edge of the A ring.

When you use high power to observe Neptune, you'll probably have to content yourself with seeing its 2.3″-diameter disk. Although Neptune is less than half the size of Saturn, it appears much smaller because it is 3.2 times farther away from Earth than Saturn is. In fact Neptune, now over 30 astronomical units (AU) from the Sun, is currently the most distant planet in the solar system.

As you devote your attention to Saturn and Neptune this month, you may want to try observing the satellites of these planets. Five of Saturn's moons are visible in a 4-inch telescope, and seven moons of Saturn and one moon of Neptune can be glimpsed in an 8-inch or larger telescope. (See "Observe the Moons of the Outer Planets" by Richard L. Talcott on page 72 for details on finding these satellites as well as the two brightest satellites of Uranus.)



Telescopic view — south at top

SATURN AND NEPTUNE pass just 18′ from each other on the morning of June 24. The two planets appear in the same field of view through an 8-inch f/10 telescope at 135x.

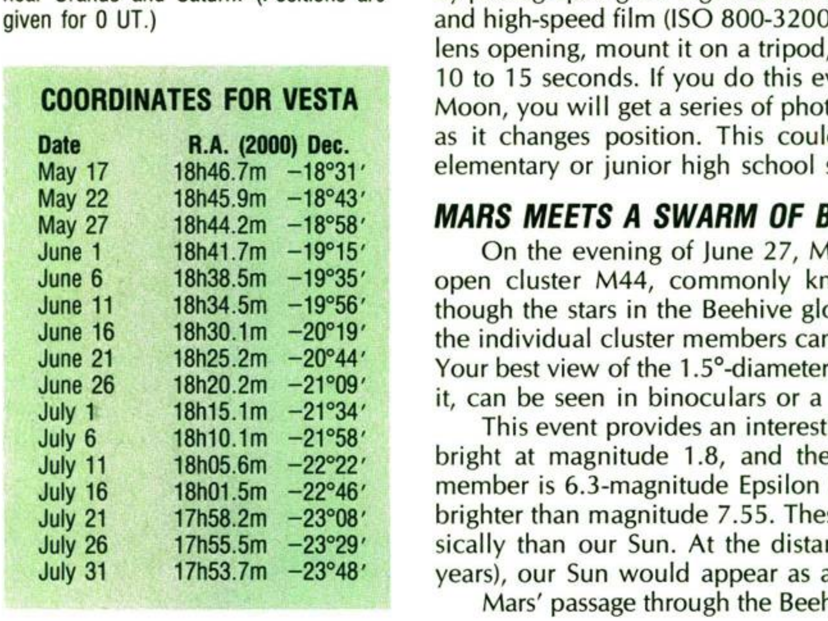
VESTA: THE BRIGHTEST OF ALL ASTEROIDS

Less than two days after Saturn and Neptune make their closest approach, asteroid 4 Vesta reaches opposition. Vesta, the brightest asteroid, lies in northern Sagittarius and can be found easily with the map below. If you look for Vesta from a dark-sky site, you will have little difficulty seeing the 5.3-magnitude object with the naked eye once you locate it with the map.

German astronomer Heinrich Olbers discovered Vesta telescopically in 1807. (Surprisingly, even though Vesta is the brightest asteroid, it was the fourth to be discovered.) This 538-kilometer-diameter chunk of rock orbits the Sun between the orbits of Mars and Jupiter at a mean distance of 2.36 AU and takes 3.63 years to complete one orbit. Although it is only the third largest asteroid, behind Ceres and Pallas, Vesta is brighter because it comes closer to Earth and has a more reflective surface.

Because Vesta is fairly bright, you can easily document its motion by photographing the region it lies in with an ordinary 35mm SLR camera and high-speed film (ISO 800-3200). Simply set the camera to its widest lens opening, mount it on a tripod, and make a time exposure of about 10 to 15 seconds. If you do this every few days during the dark of the Moon, you will get a series of photographs that displays Vesta's motion as it changes position. This could make an interesting topic for an elementary or junior high school science project.

THE BRIGHT ASTEROID VESTA moves southwest in Sagittarius during June and July. Look for this naked-eye minor planet near Uranus and Saturn. (Positions are given for 0 UT.)



COORDINATES FOR VESTA

Date	R.A. (2000)	Dec.
May 17	18h46.7m	−18°31′
May 22	18h45.9m	−18°43′
May 27	18h44.2m	−18°58′
June 1	18h41.7m	−19°15′
June 6	18h38.5m	−19°35′
June 11	18h34.5m	−19°56′
June 16	18h30.1m	−20°19′
June 21	18h25.2m	−20°44′
June 26	18h20.2m	−21°09′
July 1	18h15.1m	−21°34′
July 6	18h10.1m	−21°58′
July 11	18h05.6m	−22°22′
July 16	18h01.5m	−22°46′
July 21	17h58.2m	−23°08′
July 26	17h55.5m	−23°29′
July 31	17h53.7m	−23°48′

MARS MEETS A SWARM OF BEES

On the evening of June 27, Mars passes through the center of the open cluster M44, commonly known as the Beehive Cluster. Even though the stars in the Beehive glow at a combined magnitude of 3.1, the individual cluster members cannot be resolved with the naked eye. Your best view of the 1.5°-diameter cluster, and of Mars moving through it, can be seen in binoculars or a rich-field telescope.

This event provides an interesting contrast between Mars, relatively bright at magnitude 1.8, and the cluster stars. The brightest cluster member is 6.3-magnitude Epsilon (ε) Cancri, and there are fifteen stars brighter than magnitude 7.55. These stars are quite a bit brighter intrinsically than our Sun. At the distance of M44 (slightly over 500 light-years), our Sun would appear as a 10.9-magnitude star.

Mars' passage through the Beehive offers astrophotographers another great opportunity to shoot a series of photographs. You can use the technique described above for photographing Vesta, only this time take a photo each clear night between June 22 and July 2. Even better, use a camera and telephoto lens mounted piggyback style on a well-aligned equatorial telescope. This allows you to use a longer exposure time and yields a larger image of the objects.

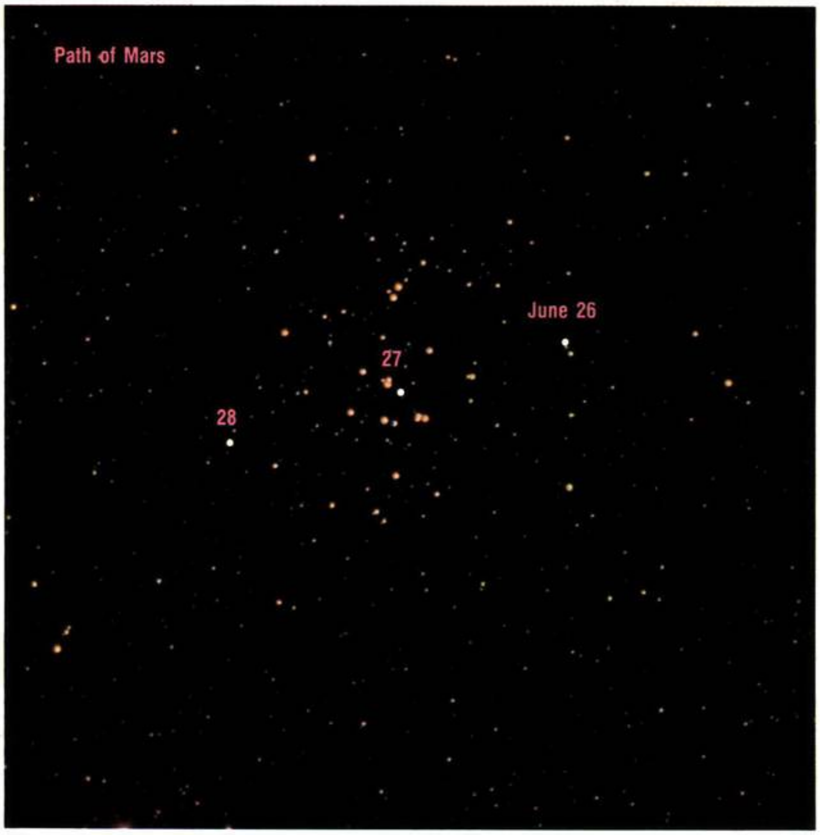
TELESCOPIC PLANETS

Mercury returns to the morning sky this month and reaches greatest western elongation on June 18. Unfortunately, early summer apparitions of Mercury are not particularly favorable, and the 23° separation of Mercury from the Sun translates into poor positioning above the horizon. If you wait to look for Mercury until half an hour before sunrise, when the Sun is 5° to 6° below the horizon, the planet will be visible only 5° to 6° above the horizon. The view of Mercury will not improve much because the sky brightens continually as Mercury climbs above the horizon in the east-northeast. The most interesting time to search for Mercury this month is on the morning of the 23rd, when the 0.1-magnitude planet passes 3° north of 0.9-magnitude Aldebaran.

Late this month Venus begins a long run in the evening sky during which it will be between 15° and 20° high at sunset. Venus remains in this position until Thanksgiving, which means that the brightest of the planets sets near the end of evening twilight for most of this apparition. Only in December will Venus spend much time in a dark sky, and then only about an hour. Viewing Venus and sketching its size and phase between now and the middle of January will give you a nice record of this evening apparition. You won't notice a substantial change in Venus' appearance over the next couple of months, but more rapid changes will occur this fall.

June is an off month for observing Jupiter. The largest of the planets passes behind the Sun on June 9, then barely comes into view in the morning sky at the end of the month. Look for −1.9-magnitude Jupiter just before sunrise during the final days of June.

Uranus reaches opposition on the night of June 24/25, when it rises at sunset, is highest in the sky around midnight, and sets at sunrise. The planet's 3.8″-diameter, blue-green disk shines at magnitude 5.6 this month. Uranus lies in Sagittarius about 8° west and 1° south of its fellow gas giants, Saturn and Neptune.



WATCH MARS PASS through the Beehive Cluster on June 26-28. The 1.8-magnitude planet lies near the Beehive's center, just 2′ south of a 6.4-magnitude cluster member, on the evening of June 27.

ASTEROIDS IN THE EYEPIECE

Although Vesta is easily the best asteroid this month, 10 Hygiea also reaches a favorable opposition on June 5/6. This 9th-magnitude asteroid passes from Ophiuchus into Scorpius and back into Ophiuchus during June. It can be found with the chart in last month's Through the Eyepiece.

THE RETURN OF A LONG-PERIOD COMET

Comet Brorsen-Metcalf pulls within 2 AU of the Sun this month on its way to a favorable apparition later this summer and fall. The comet will be high in the sky for Northern Hemisphere observers and is expected to peak in brightness at 5th or 6th magnitude as it nears perihelion in September.

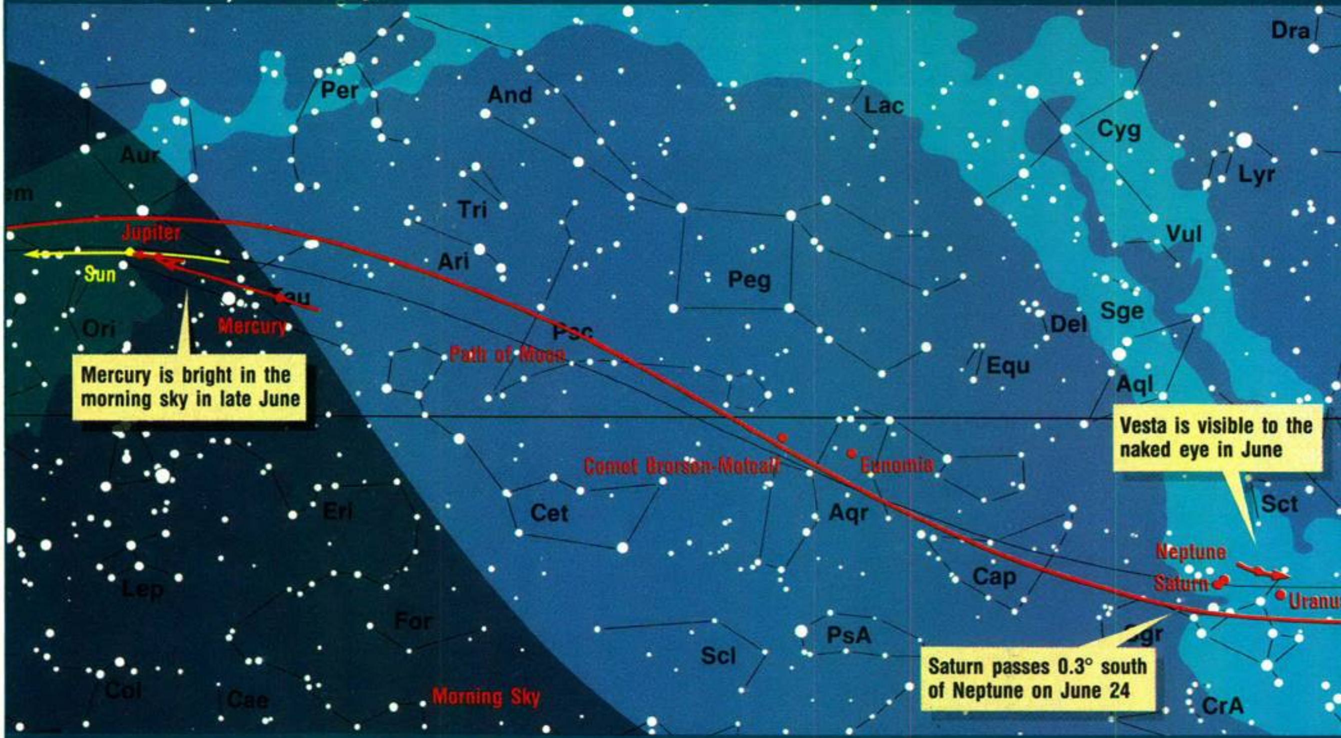
Brorsen-Metcalf moves from northeastern Aquarius into Pisces in June. The comet is faint (about 15th magnitude), so you'll need a 12-inch or larger telescope to spot it. The positions given in the table at right are only approximate because they are based on observations at the time of its last return to the inner solar system in 1919. The comet should be recovered this spring, and more accurate positions will be determined then. ASTRONOMY will keep you posted on the progress of Brorsen-Metcalf as more details become available. □

COORDINATES FOR COMET BRORSEN-METCALF

Date	R.A. (2000)	Dec.
June 1	22h50.8m	−6°03′
June 6	22h57.3m	−4°56′
June 11	23h03.8m	−3°43′
June 16	23h10.6m	−2°24′
June 21	23h17.7m	−0°58′
June 26	23h25.1m	0°39′
July 1	23h32.9m	2°28′

Positions are given for 0 UT.

The Solar System June 1989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Sge
Path of Moon
Equ
Aql
Mercury is bright in the morning sky in late June
Vesta is visible to the naked eye in June
Comet Brorsen-Metcalf
Eunomia
Eri
Cet
Aqr
Sct
Neptune
Saturn
Uranus
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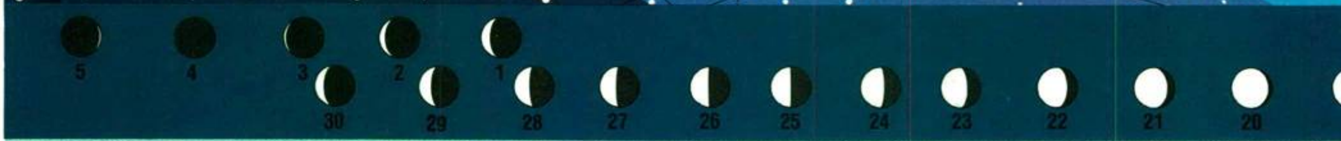
Saturn passes 0.3° south of Neptune on June 24
Col
Cae
Morning Sky
CrA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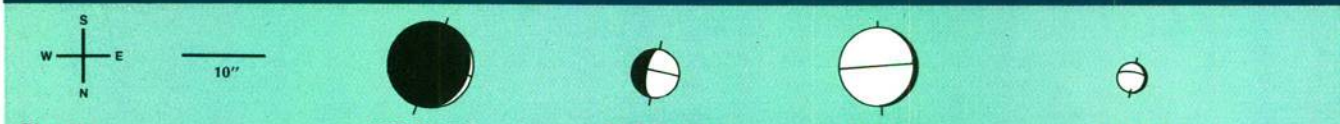
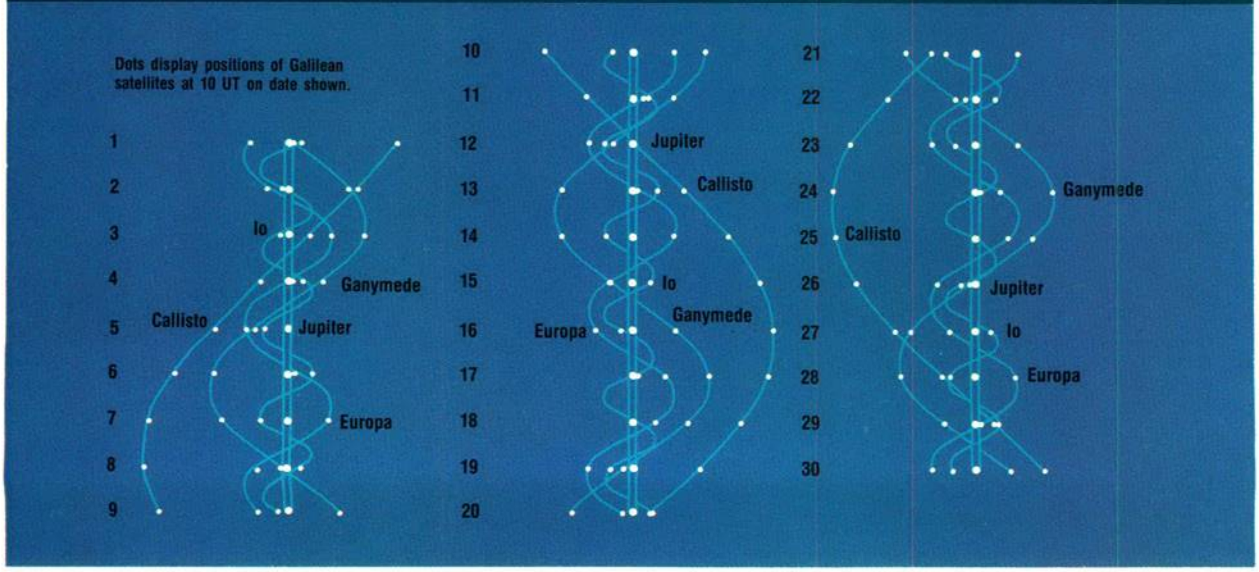
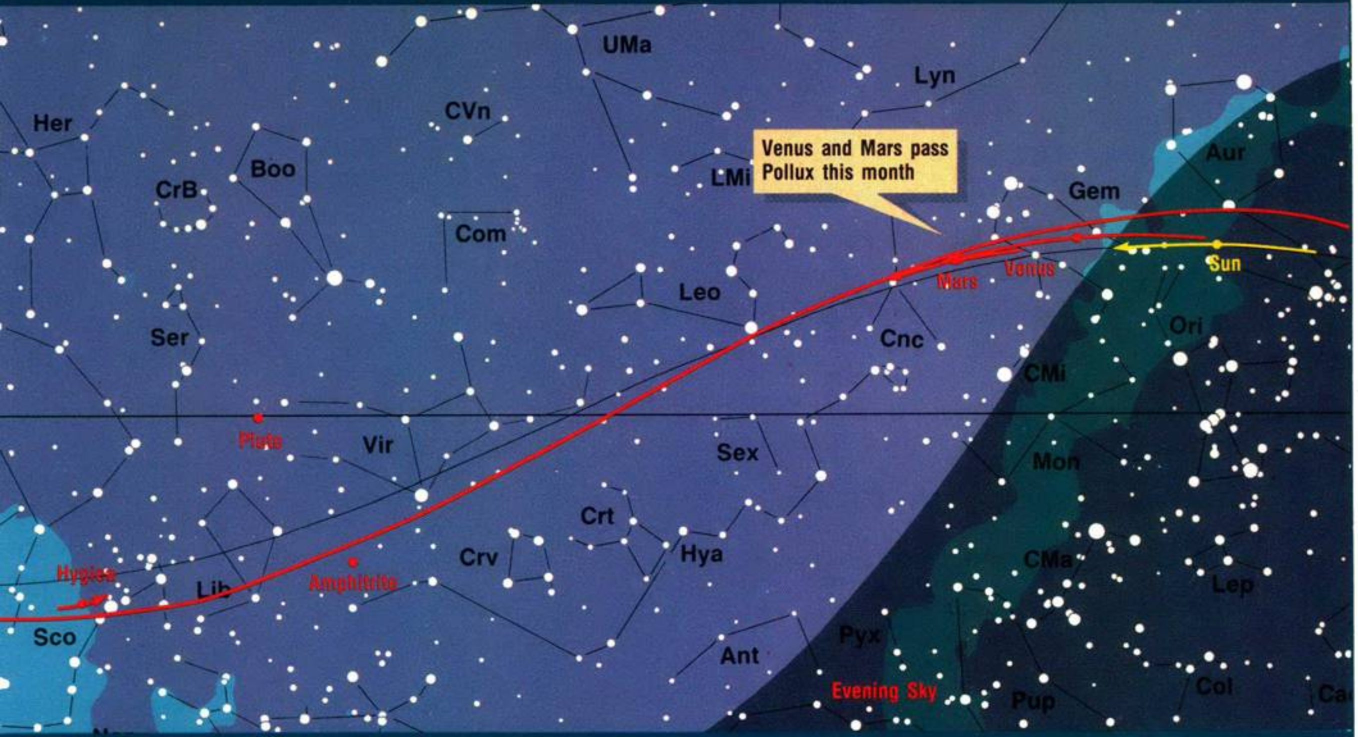


Planet	MERCURY	MERCURY	VENUS	MARS
Date	June 1	June 30	June 15	June 15
Magnitude	+3.3	−0.5	−3.9	+1.8
Angular Size	11.65″	6.30″	10.4″	3.9″
Illumination	6%	65%	95%	97%
Distance (AU) from Earth	0.578	1.067	1.602	2.383
Distance (AU) from Sun	0.466	0.347	0.718	1.659
Right Ascension (2000.0)	3h50.1m	5h14.5m	6h55.8m	8h06.4m
Declination (2000.0)	16°37′	21°31′	24°03′	21°35′

Jupiter's Moons

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Pluto
Vir
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Mon
Crt
Hyga
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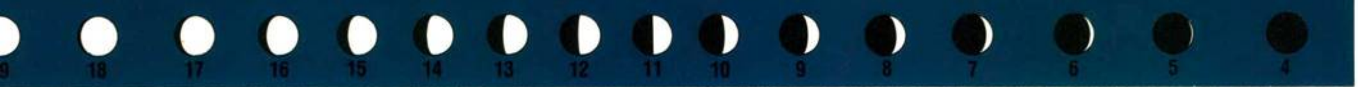
Venus and Mars pass Pollux this month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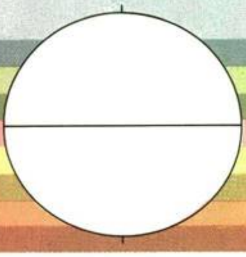
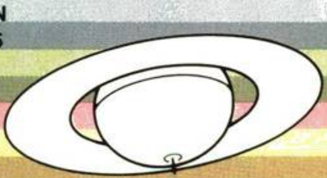
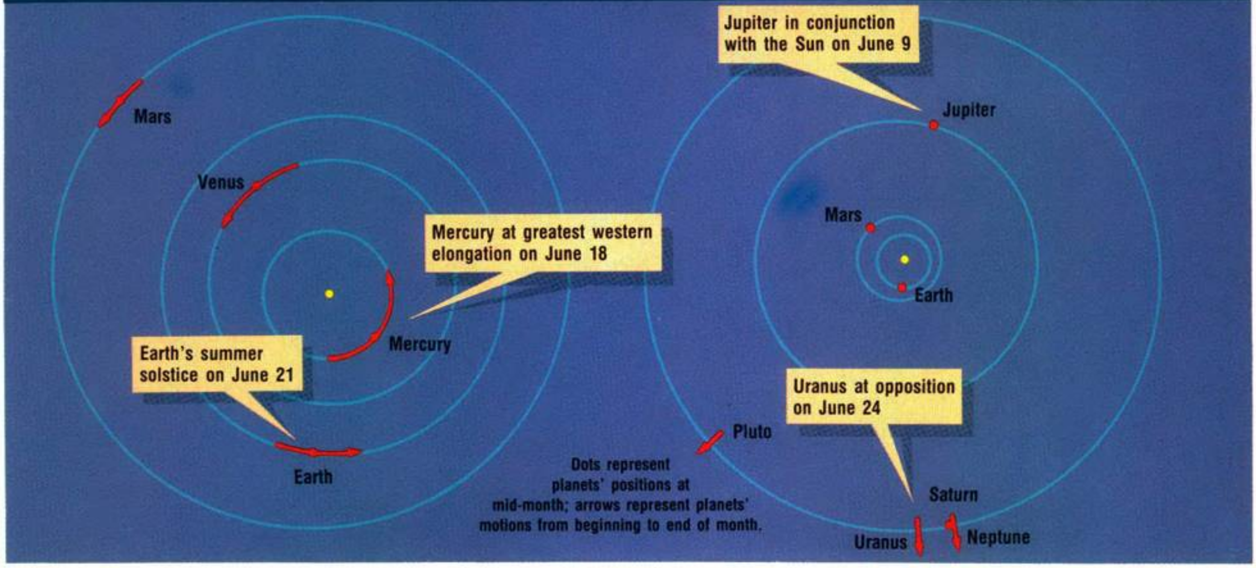




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
June 30	June 15	June 15	June 15	June 15
−1.9	+0.1	+5.6	+7.9	+13.7
32.5″	18.2″	3.8″	2.3″	0.1″
100%	100%	100%	100%	100%
6.062	9.068	18.343	29.246	28.913
5.087	10.039	19.344	30.215	29.656
5h31.4m	18h52.0m	18h17.0m	18h50.2m	15h01.1m
22°54′	−22°15′	−23°39′	−22°00′	−0°16′

The Planets in Their Orbits


Mars
Venus
Mercury
Earth
Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Jupiter in conjunction with the Sun on June 9

Mercury at greatest western elongation on June 18

Earth's summer solstice on June 21

Uranus at opposition on June 24

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

The Secrets of My Astrophotography Success

Spend the night behind the camera with a veteran astrophotographer to find out exactly how he gets such great results.

by Kim Zussman

Astrophotography gives me a great feeling. Capturing starlight from distant galaxies and nebulae and storing it away for a cloudy night has become an obsession. After experimenting with astrophotography for four years, I have come to know what makes it work well and what prevents it from working well. If you're someone who loves the stars, I strongly suggest you experiment with astrophotography. I've found it to be the single most rewarding area of amateur astronomy.

When I decided to try my hand at astrophotography, I carefully thought about several things. First, I decided what types of objects I was most interested in recording on film. My favorite objects are galaxies, but I also enjoy photographing nebulae and globular clusters. I wanted to capture a lot of detail in my photos. And I also wanted equipment that was truly manageable by one person.

Based on these requirements, I chose an 11-inch f/10 Schmidt-Cassegrain telescope. The long focal length and correspondingly large image scale lets me record small- and medium-sized objects. This system also permits me to capture fine details in these objects when used with high-resolution film.

After deciding on a telescope, you'll have to think about its mounting. When I first became interested in astrophotography in 1984, I had the good fortune to tag along with Martin Germano on a photography session. Marty was an old pro at taking deep-sky photos; for years his photos had appeared in ASTRONOMY and *Deep Sky*. After setting up his 8-inch SCT, he found a guide star and used what *I then considered* the ridiculously high guiding magnification of 500x.

Out of the darkness I heard Marty call me over and ask me to tap the telescope. I tapped it while looking into the eyepiece, and the guide star didn't move. Marty taught me the most important rule for successful astrophotography: no matter what optical system you set on top of it, you need a massive, solid mounting.

This often means added cost and effort. One of the first things I did after I bought my 11-inch f/10 SCT was to replace the mounting that came with it. I bought a mount from Bill Schaefer, a telescope maker who lives in Fullerton, California. The mount is rock steady and is probably overkill for the 11-inch telescope, but in astrophotography it is always better to overdo it than to underdo it. A custom-made mount isn't necessary, mind you, but a heavy-duty one that won't shake in the wind or vibrate after being tapped is necessary.

"EQUIPMENT IS EVERYTHING in astrophotography," says Kim Zussman, shown here sitting beside his 11-inch f/10 SCT on a heavy-duty mount.

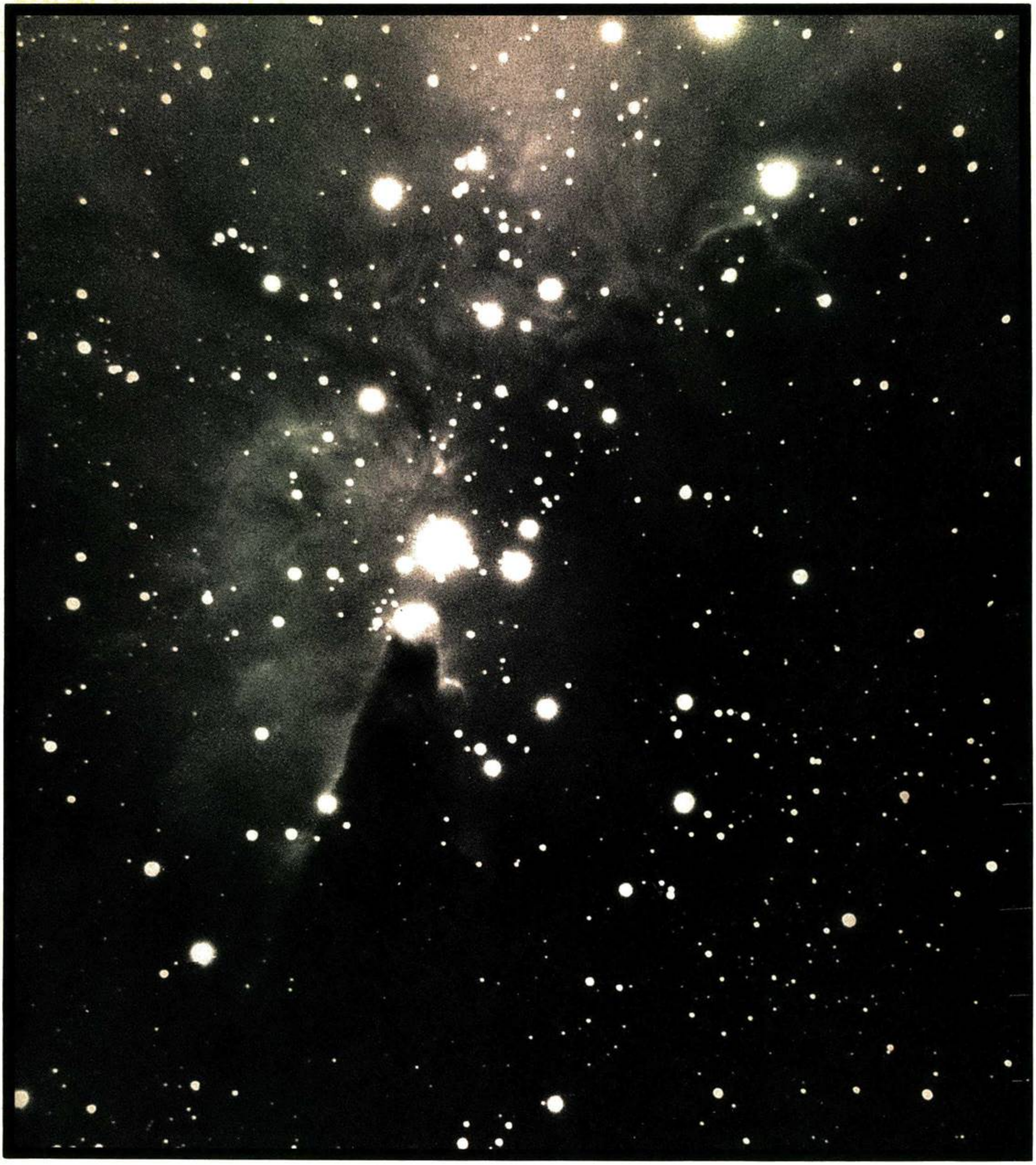
I made changes in the telescope's optical system as well. After using a commercial 11-inch SCT for some time, I found that it would not produce perfectly sharp star images all the way across the field. So, with the help of a friend who is an optical expert, I dismantled the telescope and modified it by respacing the corrector plate. This proved to be a tricky procedure that gave me a slight improvement in star images, but it's certainly not necessary to produce nice astrophotos.

Third in importance after the telescope and mounting is a reliable drive corrector. The drive corrector is the control box that links your eye's view of a guide star and the telescope's motors. You need a drive corrector that instantly and perfectly responds to corrections in right ascension and declination, so the stars in your photos won't appear trailed.

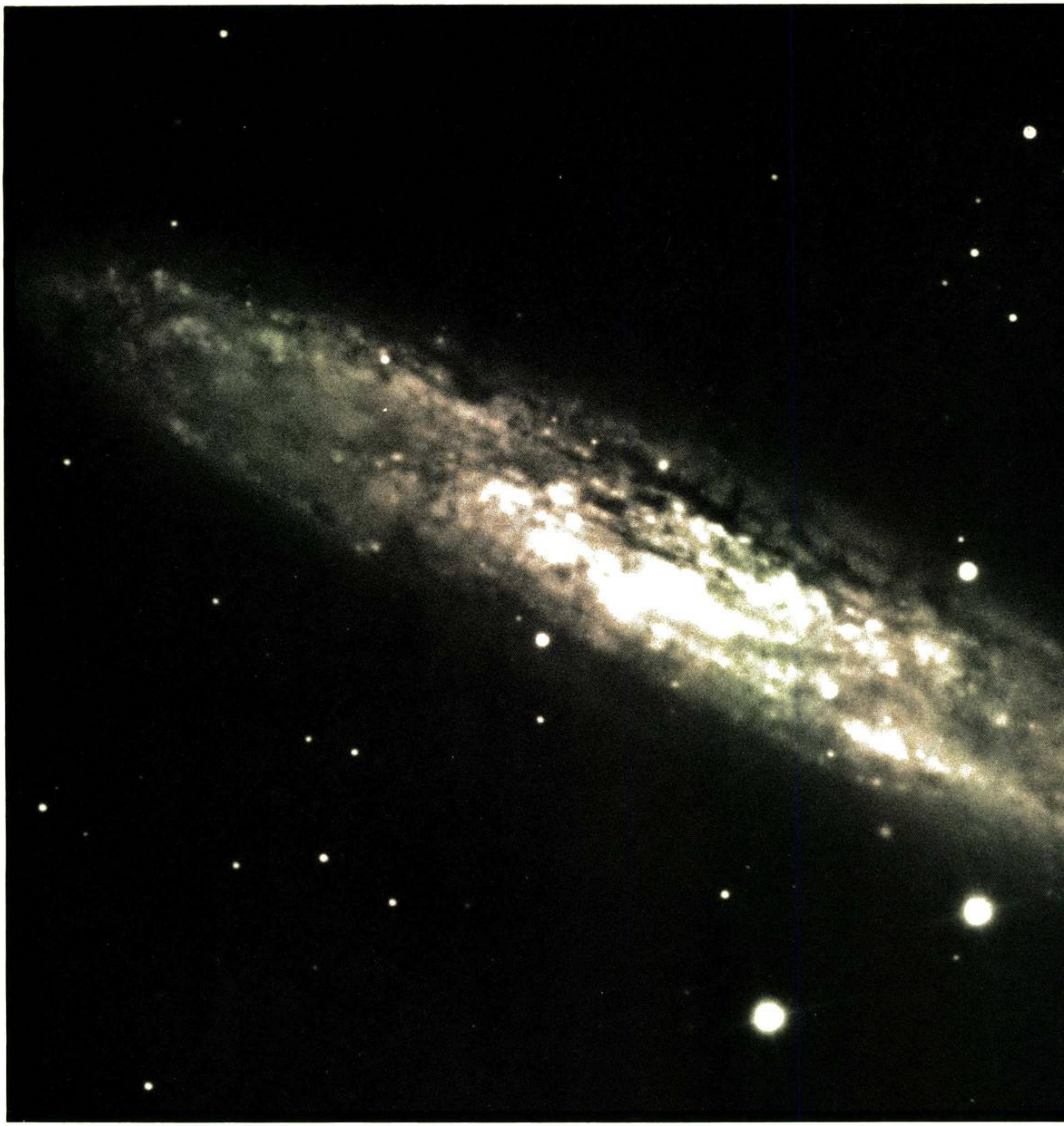
There are many good drive correctors on the market today. Those sold by Celestron, Lumicon, Meade, and Orion all perform well. Make sure the one you get lets you make corrections in both right ascension and declination. Also be sure that you can return it if you find it doesn't work properly. I built my own drive corrector, because at the time I wanted a fun little electronics project. It works beautifully.

One of the biggest equipment decisions you'll make is whether to use an off-axis guider or a separate guide telescope. An off-axis guider fits between the telescope and the camera and contains a small prism, which diverts light from the picture-taking optics into a guiding eyepiece. A separate guidescope is usually a 2-inch or 3-inch refractor that is piggybacked on the main instrument.

I chose an off-axis guider rather than a separate guidescope. Off-axis guiders let you guide using the main scope's optics, which avoids the problem of flexure. Flexure occurs when the guidescope moves slightly relative to the main scope and produces trailed stars. I've found that the Giant Easy Guider by Lumicon allows selec-



THE CONE NEBULA, NGC 2264
11-inch f/10 Schmidt-Cassegrain telescope
180-minute exposure on hypersensitized Tech Pan film
November 22, 1987



SPIRAL GALAXY NGC 253
11-inch f/10 Schmidt-Cassegrain telescope
90-minute exposure on hypersensitized Tech Pan film
August 19, 1988

tion of a reasonably bright guide star for practically any object I want to shoot.

I don't use filters because with a large image scale and long focal ratio, I find no reason to. I want to get as much light as I can.

Focal ratios dictate whether or not filters are useful. Shorter focal ratios record light faster and benefit from filters. Longer focal ratio systems don't benefit from filters. At f/3 you might want a red filter for recording emission nebulae and retarding sky fog (the point at which background skylight fogs the film). At f/10, sky fog isn't a problem. You can go all night with some films.

Films play an important role in astrophotography. In effect they function as equipment that's as important as your scope and drive corrector. Armed with the best optics, mount, and guider available, your astrophotos will not turn out well unless you use the right film.

The Power of Black and White

I use Kodak Tech Pan 2415 for all of my astrophotography. For my needs, no other film can touch it. Tech Pan is a high-resolution black-and-white film that's crisp, sharp, and virtually grainless.

People I talk to are surprised that I so strongly recommend shooting black and white. When I started taking sky photos I used color film, because I wanted to duplicate the pretty sights I saw each month in magazines. However, the more I learned about color films, the less I liked them.

Color films don't lend themselves well to astrophotography. Generally they are grainy. From my experience they produce low-contrast images of faint objects and rarely yield a satisfyingly "real" colored background or a faithful rendition of colored stars or nebulosity.

Tech Pan has two very desirable characteristics for astronomical photography: extremely fine grain and low reciprocity failure, or the ability to retain most of its original speed during a long exposure. However, it has one undesirable characteristic for astrophotography: it's exceedingly slow.

Tech Pan's ability to record faint light can be increased dramatically by hypersensitization. This process exposes the film to a mixture of nitrogen and hydrogen called forming gas. Hypersensitization increases Tech Pan's speed significantly enough to make it the best film available for photographing the sky.

You can get hypered Tech Pan two ways: buy rolls of hypered film through the mail or get your own hypering equipment and prepare them yourself. Film hypersensitizing is a reasonably simple process, but it involves purchasing a specialized tank, supplies of forming gas, and accessories. The cost is approximately $400.

From my experience it's best to buy a few rolls from mail-order dealers and see what you think of the film's performance. After all, you might not even want to do astrophotography a year from now. If you get serious, however, you'll save money in the long run by purchasing your own hypersensitizing kit.

If you become serious about astrophotography, you should also set up a darkroom. Processing your own film is almost a must if you use hypered Tech Pan, because the lab down the street is set up for developing photos of Mom and Pop at the beach; they've probably never seen an astronomical negative. The only way to ensure quality is to do it yourself. You can set up a darkroom in your basement, attic, or bathroom, and the cost of a developing tank and chemicals probably won't exceed $100. For more information, consult your local photo shop.

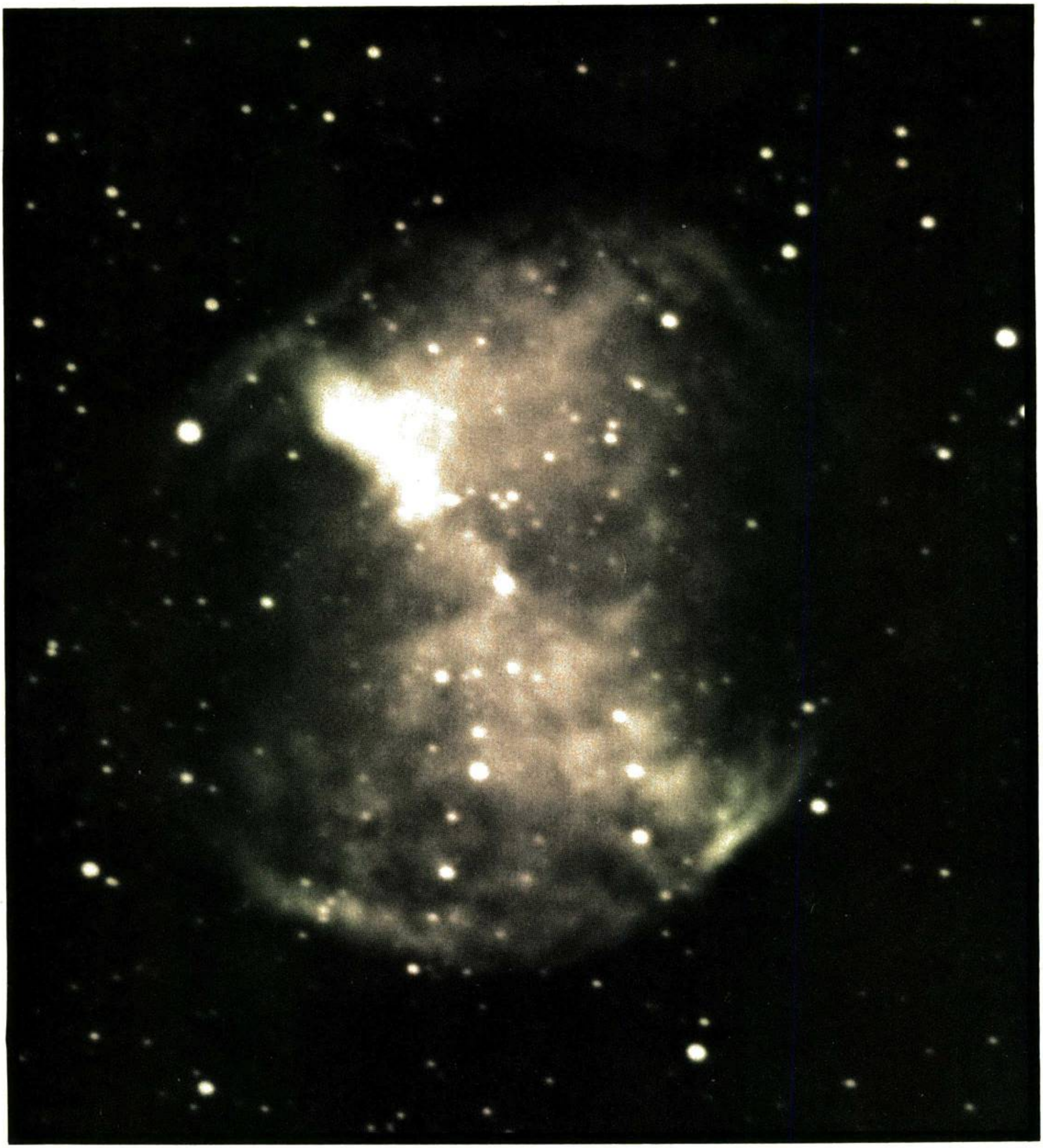
A Night Out on the Mountain

Getting the right equipment is a prerequisite for deep-sky astrophotography, but a good observing site can make the difference between good and great photos. You need a site that's accessible, offers a reasonably dark sky, and affords no surprises such as cars driving past during a one-hour exposure. This place may be your backyard, it may be the local nature park just over the county line, or it may be, as in my case, a mountaintop more than an hour away.

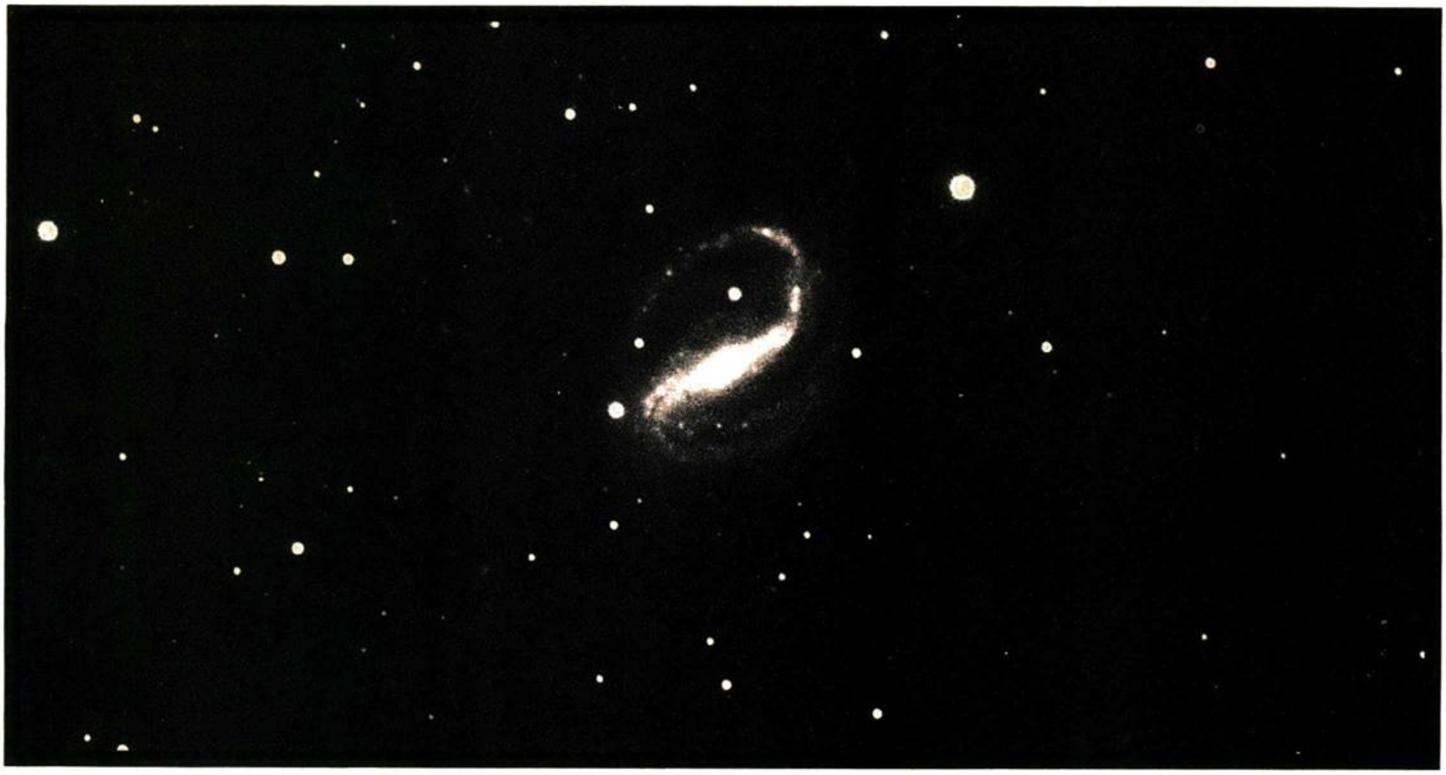
Mount Pinos is a popular gathering place for southern California astrophotographers. It's about one hundred miles northwest of Los Angeles, and has a paved parking lot near the 8,831-foot summit where I can set up my equipment and take astrophotos relatively undisturbed. There's a fair degree of wind protection from trees that ring the parking lot. (This is important, especially at that altitude.)

Sky darkness is an important consideration for shooting deep-sky objects. The sky over Pinos is reasonably dark, but varies considerably from night to night. At times a cloud layer covers the Los Angeles basin and the sky is *really* dark. On cloudless nights the sky looking south toward Los Angeles appears bright along the horizon.

When I head off for a night of astrophotography I like to leave during the day. I pack all of the gear I need in my car and arrive a couple of hours



THE DUMBBELL NEBULA
11-inch f/10 Schmidt-Cassegrain telescope
60-minute exposure on hypersensitized Tech Pan film
July 30, 1987



BARRED SPIRAL GALAXY NGC 7479
11-inch f/10 Schmidt-Cassegrain telescope
150-minute exposure on hypersensitized Tech Pan film
November 6, 1988

before dusk. This way I have time to think things through, set up the equipment, and go over lists of objects I want to photograph.

I set up the telescope early so that it cools to the outside temperature before I begin photography. As soon as darkness falls I polar align and collimate the telescope, load the camera with film, prepare the accessories, and generally relax and get ready for guiding.

Once I'm ready to begin I'll locate the object in the finder scope and frame it in the camera. Generally I center objects within the field, but I also like to include bright stars with a nebula to make as pretty a picture as possible. Next I acquire a suitable guide star in the off-axis guider and make sure the telescope is locked and tracking well. After centering the guide star at low power, I'll move the telescope away from the field to a bright star and, using a magnifying eyepiece on the camera, critically focus the camera on the bright star and surrounding field.

Then I move the scope back to the photographic field, center the guide star, and switch to about 600x for guiding. I align the illuminated reticle in the guiding eyepiece north-south and east-west by watching the star drift and rotating the cross hair, then place the guide star comfortably in the center of the reticle. At 600x the star is usually a blob (unless the seeing is particularly good), but I've found that extremely high magnifications allow you to catch tiny drifts and correct them well before they're visible on the film. Blob guiding really works.

After making sure that all is tracking well, I start the exposure and concentrate on staring at the guide star, while keeping track of time with a simple timer. I make sure that I record all the pertinent information about each photo in a log book. This valuable record has helped me to avoid many goofs later on.

After shooting the first object, I simply repeat the process on other objects until I am too tired to go on anymore. Hopefully by this time I'll have at least three or four good negatives. If things didn't go well I may come away without any good negatives, but if everything went without a hitch I may have a half dozen or more negatives. This makes a night of photography.

A professional astronomer recently told me that with all of the new high-tech forms of recording astronomical images, pros may eventually stop using photography. While that may be somewhat of an exaggeration, it's already true that professional astronomers use photography less and less. CCDs are supplanting photography as the medium of choice.

Whatever the future of deep-sky photography, even with the right equipment, films, and techniques, it is not an easy process. It is tricky and frustrating, especially at first. But it doesn't remain frustrating. I went from being a hapless beginner with no background in astrophotography to taking galaxy photos I was proud of in four years. You can too. ☐

Kim Zussman is a periodontist by profession who lives in Thousand Oaks, California. He says, "Some day I'll get a 20-inch telescope and shoot everything over again."

Observe the Moons of the Outer Planets

Take on the challenge of observing the satellites of Saturn, Uranus, and Neptune in 8-inch or larger telescopes.

by Richard L. Talcott

Almost every telescope owner has at one time or another observed the Galilean satellites of Jupiter. The four bright Jovian moons are easy to see even in binoculars, and because they usually lie in a line with each other and with the planet's equator, they are easy to recognize.

What many telescope owners don't realize, however, is that the three outer gas giant planets — Saturn, Uranus, and Neptune — also have their own retinue of satellites. Although they are more difficult to spot than the Galilean moons, these often neglected satellites are within the reach of many backyard telescopes. With a little bit of effort you can see firsthand what most observers have seen only in pictures, if at all.

A 4- to 6-inch telescope easily shows five moons of Saturn, and an 8- to 10-inch scope reveals two additional satellites. At Uranus you'll need all the light-gathering power of an 8-inch telescope to spot its two brightest moons; an 8-inch scope is also necessary to see Neptune's brightest moon.

The key to finding most of these moons is knowing exactly where to look. By planning your observations of the outer planets ahead of time, you can calculate where each satellite will be in its orbit relative to greatest elongation, the maximum apparent distance of the satellite from the planet.

Saturn's Unique System

The most varied and interesting of the three satellite systems is Saturn's. The satellites range from the large and bright moon Titan to the tiny and faint moon Mimas. The Saturnian satellites also have vastly different orbital periods. Mimas, the innermost satellite, orbits Saturn once every 23 hours, while Iapetus, the most distant bright satellite, takes 80 days to circle Saturn once.

The first moon you'll spot is magnitude 8.3 Titan, the second largest moon in the solar system, with a diameter of over 5,000 kilometers. Titan is so bright that it is visible in almost any telescope and is the one moon you can usually identify without knowing its location beforehand. Titan orbits Saturn once every 16 days and reaches a maximum separation of nearly 200″ (about five ring diameters) from the planet. Under exceptional conditions with an 8-inch or larger telescope, you may be able to detect a faint orange tinge to Titan's color.

A 4-inch telescope reveals three more Saturnian satellites: Rhea, Tethys, and Dione. Rhea is the second largest Saturnian satellite, just over 1,500 kilometers in diameter, and second brightest at magnitude 9.7. Tethys and Dione are both a little over 1,000 kilometers in diameter and shine at magnitude 10.2 and 10.4, respectively. These three satellites orbit closer to Saturn than Titan does, but are still far enough away from the ringed planet to be spotted easily.

The most unusual Saturnian moon, and in some ways the most unusual moon in the solar system, is Iapetus. This satellite varies by a factor of ten in brightness depending on where it is in its orbit. At western elongation it shines at magnitude 10.1 and is easy to see in a 4-inch scope; at eastern elongation it glows at magnitude 11.9 and is quite hard to see in less than a 6-inch scope.

Iapetus varies in brightness because its surface is divided into two very different hemispheres. The hemisphere we see at western elongation reflects 50 percent of the sunlight striking it, about the same as freshly fallen snow. The hemisphere facing Earth at eastern elongation, however, is as black as coal and reflects only 5 percent of the sunlight falling on it.

Iapetus' 80-day orbit is the largest orbit of any of Saturn's bright satellites. At its maximum distance Iapetus is more than 9.5′ from Saturn. (To keep this in perspective, remember that Neptune appears just 18′ from Saturn when they are in conjunction in late June.)

Two Tough Ones

The two innermost moons of Saturn — Mimas and Enceladus — are also the most difficult to see. This is not because they are extremely faint, but because they orbit so close to Saturn's rings. In fact, these satellites are particularly difficult to see now because Saturn's rings appear wide open from our vantage point and create a lot of glare.

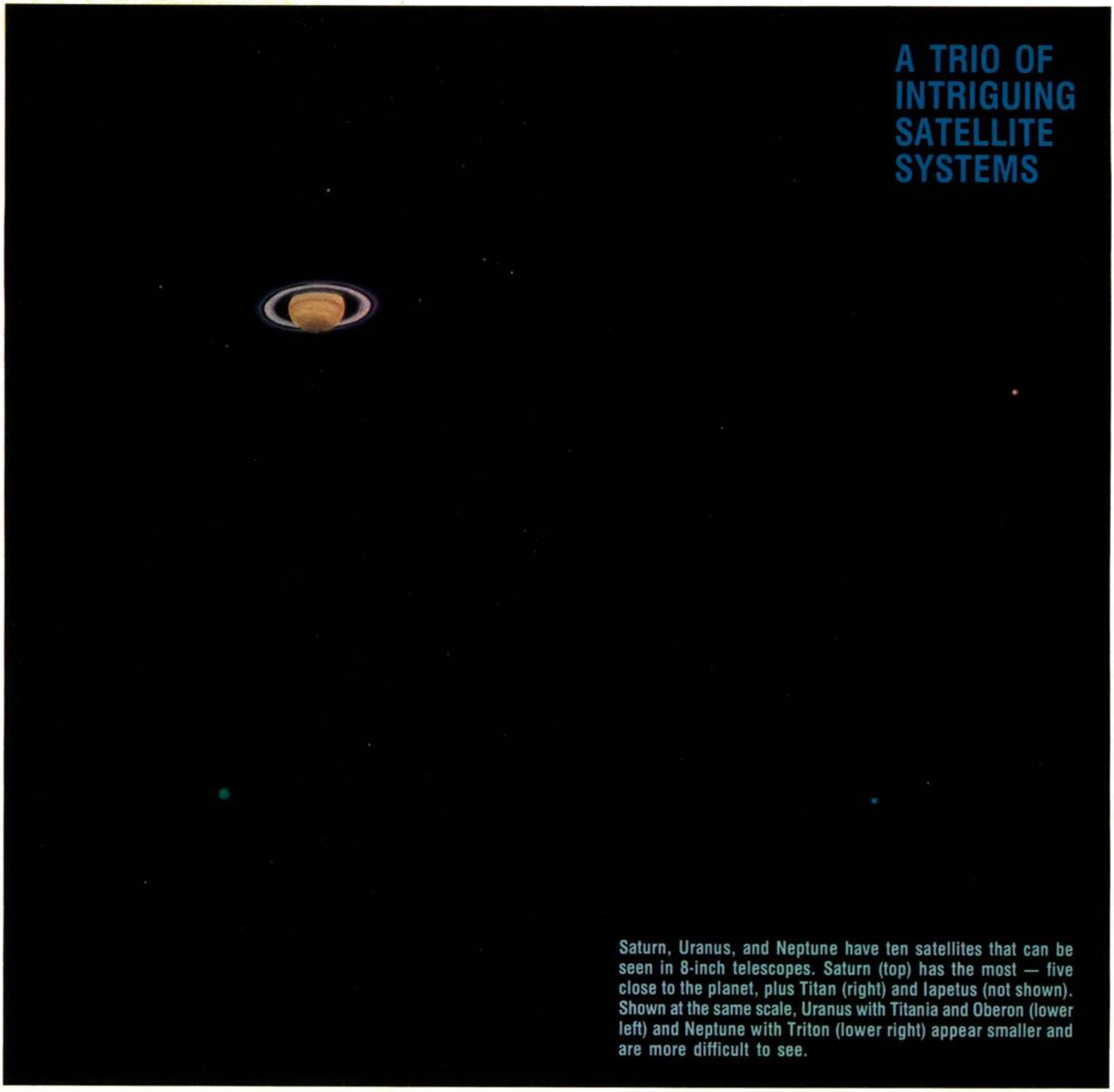
The key to spotting Mimas and Enceladus is to look for them at eastern or western elongation with at least an 8-inch telescope. A 10-inch or larger scope makes the task easier. (Times of eastern elongation are given in the table on page 77; times for western elongation occur halfway between the tabulated values.)

Enceladus will appear as an 11.7-magnitude speck about 38″ from Saturn's center. Its main claim to fame is that it is the most reflective body in the solar system: it reflects almost 100 percent of the sunlight striking it. Mimas is even harder to spot than Enceladus. The smallest of Saturn's major moons shines at magnitude 12.9 and appears at most 30″ from the planet's center, which is less than 10″ from the outer edge of Saturn's rings.

Only two of Uranus' five major moons are bright enough to be glimpsed in an 8-inch telescope. As with Mimas, your chances of seeing them are better with a larger scope. Titania is a 13.7-magnitude object located 33″ from Uranus at greatest elongation; Oberon is a 13.9-magnitude object located 44″ from the planet.

There are two factors working in your favor to help you see these moons, however. Uranus is much

A TRIO OF INTRIGUING SATELLITE SYSTEMS



Saturn, Uranus, and Neptune have ten satellites that can be seen in 8-inch telescopes. Saturn (top) has the most — five close to the planet, plus Titan (right) and Iapetus (not shown). Shown at the same scale, Uranus with Titania and Oberon (lower left) and Neptune with Triton (lower right) appear smaller and are more difficult to see.

fainter than Saturn, therefore, it casts nowhere near as much glare. Also, Uranus is tilted almost pole-on to Earth, so its satellites appear to follow circular orbits around the planet, which means you can look for them at any time, not just at elongation.

The last moon observable with a backyard telescope belongs to the outermost planet in the solar system, Neptune. Triton is a 13.5-magnitude satellite located at a maximum distance of 17" from Neptune. Although it appears closer to its planet than any of the other moons on our list, it is not as difficult to see as the Uranian moons because it is slightly brighter and Neptune has less glare.

A Simple Five-Step Process

Each of the ten observable satellites follows a predictable orbit around its planet, which means to find each moon, you just have to pinpoint its orbital position. For any day and time in June or July, you can use the worksheet on page 76 and the tables on page 77 to calculate where the moons are, and then plot them on a diagram showing the planet's telescopic appearance.

First, make a copy of the worksheet. (If you make several copies at once, you'll be set for a whole summer of satellite observing.) Next, pick a convenient time to observe. Then convert your chosen observing time into universal time (UT), which is an unambiguous system of reckoning time used by astronomers throughout the world. Universal time, which is based on a 24-hour clock, allows astronomers to specify dates and times independent of time zones.

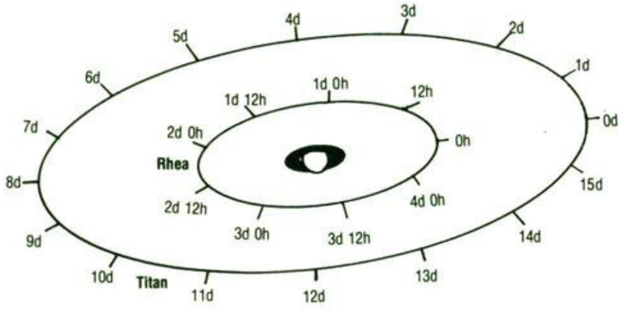
To convert your local daylight time into UT, add 4 hours to EDT, 5 hours to CDT, 6 hours to MDT, 7 hours to PDT, 8 hours to Alaska, and 9 hours to Hawaii. For example, if you want to observe at 9:00 p.m. MDT on June 15, add 6 hours to obtain 3:00 UT on the next day, June 16. If you live in an area that remains on standard time, add an additional hour.

Now you have to ascertain where

PINPOINTING THE SATELLITES

Use the worksheet below to calculate where each satellite will be at the time you plan to observe. Take your planned observing time and convert it to universal time (see text for details). Then find the most recent previous elongation for each satellite in the tables, given in hours and decimals of hours on the opposite page, and subtract this time from the UT of observation to get the elapsed time differences. Use these elapsed times to plot the satellites' positions on the diagrams. South is at top and east at right to match a telescope's field of view.

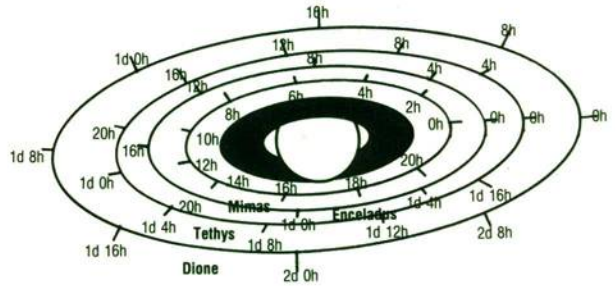
Saturn's Outer Satellites



5d
4d
3d
2d
1d
6d
1d 12h
1d 0h
12h
7d
2d 0h
0h
0d
Rhea
8d
15d
2d 12h
4d 0h
9d
3d 0h
3d 12h
14d
13d
10d
Titan
11d
12d

Satellite	Local Time		Conversion Factor	UT of Observation		UT of Previous Elongation		Difference	
	Date	Time	Hours	Date	Time	Date	Time	Days	Hours
Rhea									
Titan									

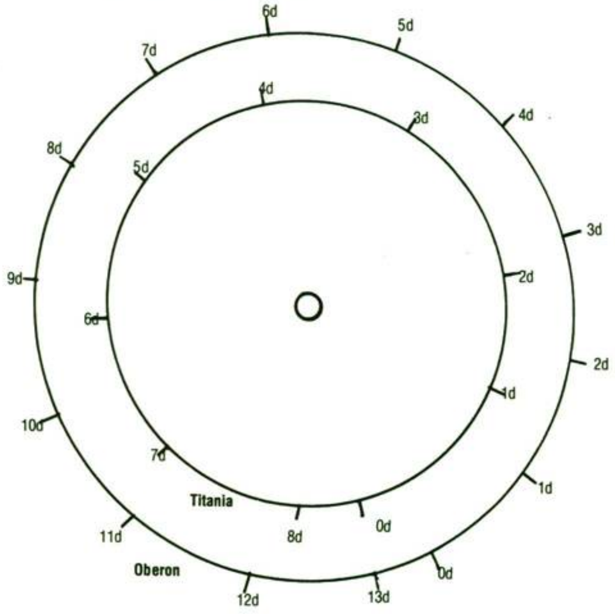
Saturn's Inner Satellites



16h
1d 0h
12h
8h
8h
16h
12h
8h
4h
4h
6h
4h
2h
8h
0h
0h
0h
0h
20h
10h
1d 8h
16h
12h
20h
1d 0h
14h
16h
18h
1d 4h
1d 16h
20h
Mimas
Enceladus
1d 4h
Tethys
1d 0h
1d 12h
2d 8h
1d 8h
1d 16h
Dione
2d 0h

Satellite	Local Time		Conversion Factor	UT of Observation		UT of Previous Elongation		Difference	
	Date	Time	Hours	Date	Time	Date	Time	Days	Hours
Mimas									
Enceladus									
Tethys									
Dione									

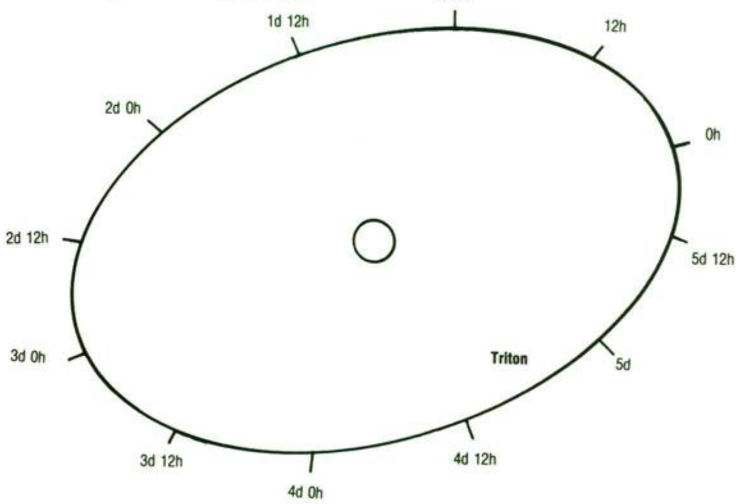
Uranus' Satellites



6d
5d
7d
4d
3d
4d
8d
5d
3d
9d
2d
6d
2d
1d
10d
7d
1d
Titania
11d
8d
0d
Oberon
0d
12d
13d

Satellite	Local Time		Conversion Factor	UT of Observation		UT of Previous Elongation		Difference	
	Date	Time	Hours	Date	Time	Date	Time	Days	Hours
Titania									
Oberon									

Neptune's Satellite



1d 0h
1d 12h
12h
2d 0h
0h
2d 12h
5d 12h
3d 0h
Triton
5d
3d 12h
4d 12h
4d 0h

Satellite	Local Time		Conversion Factor	UT of Observation		UT of Previous Elongation		Difference	
	Date	Time	Hours	Date	Time	Date	Time	Days	Hours
Triton									

each moon lies at the calculated UT by figuring how far in its orbit the moon has traveled from a fixed point. The fixed point astronomers use is a satellite's greatest elongation. (For Saturn and Neptune this is greatest eastern elongation; for Uranus it is greatest northern elongation.)

The universal times for all the greatest elongations in June and July are listed at left. For each satellite, find the elongation that occurred most recently and write it in on the worksheet. Then subtract this time from the UT at which you'll be observing and write in this elapsed time in the last column of the worksheet.

The elapsed time fixes the satellite's position in its orbit. Find that time on the orbital diagram (in most cases you'll have to interpolate between the labelled times) and mark the position. Repeat the process for the rest of the moons. The resulting diagram will represent what you'll see through the eyepiece of your telescope.

Iapetus is not shown on the diagram of Saturn's satellites because its orbit is too large. Look for Iapetus in the week around its western elongation, which occurs on July 23 when it lies 9.5′ west of Saturn.

Finding the Planets

When the appointed time comes, you should have your telescope set up and be ready to observe. Fortunately, Saturn, Uranus, and Neptune lie within 10° of each other in Sagittarius this summer. Saturn shines at zero magnitude — the brightest "star" in that region of the sky — and lies slightly above the Teapot asterism.

Uranus is a 5.6-magnitude planet that lies approximately 8° west and 1° south of Saturn. It is distinguishable at high power by its 3.8″-diameter disk and slight blue-green color. Neptune shines at magnitude 7.9 but is currently easy to find because of its proximity to Saturn. The most distant planet passes just 18′ north of Saturn on June 24, and the two remain within 2° of each other throughout June and July.

Ten moons, ten separate observing challenges. The satellites of the outer planets are an intriguing mix: large and small, bright and dim, near to their planets, and far away. But more than that, these objects open observing opportunities for everyone. A beginner with a small telescope can see five moons, probably double the number of moons he or she has seen around all the planets combined, while an advanced observer can try for some of the most difficult solar system targets of all. It's an opportunity that promises big rewards to anyone who wants a challenge. ☐

SATURN

MIMAS

Date	Time
May 31	21.9
June 1	20.5
June 2	19.1
June 3	17.8
June 4	16.4
June 5	15.0
June 6	13.6
June 7	12.2
June 8	10.8
June 9	9.4
June 10	8.0
June 11	6.7
June 12	5.3
June 13	3.9
June 14	2.5
June 15	1.1
June 15	23.7
June 16	22.3
June 17	20.9
June 18	19.6
June 19	18.2
June 20	16.8
June 21	15.4
June 22	14.0
June 23	12.6
June 24	11.2
June 25	9.9
June 26	8.5
June 27	7.1
June 28	5.7
June 29	4.3
June 30	2.9
July 1	1.5
July 2	0.1
July 2	22.8
July 3	21.4
July 4	20.0
July 5	18.6
July 6	17.2
July 7	15.8
July 8	14.4
July 9	13.1
July 10	11.7
July 11	10.3
July 12	8.9
July 13	7.5
July 14	6.1
July 15	4.7
July 16	3.4
July 17	2.0
July 18	0.6
July 18	23.2
July 19	21.8
July 20	20.4
July 21	19.0
July 22	17.7
July 23	16.3
July 24	14.9
July 25	13.5
July 26	12.1
July 27	10.7
July 28	9.3
July 29	8.0
July 30	6.6
July 31	5.2

IAPETUS

Date	Time
March 27	13.2
June 14	13.9

ENCELADUS

Date	Time
May 30	16.0
June 1	0.9
June 2	9.7
June 3	18.6
June 5	3.5
June 6	12.4
June 7	21.2
June 9	6.1
June 10	15.0
June 11	23.9
June 13	8.8
June 14	17.6
June 16	2.5
June 17	11.4
June 18	20.2
June 20	5.1
June 21	14.0
June 22	22.9
June 24	7.7
June 25	16.6
June 27	1.5
June 28	10.4
June 29	19.2
July 1	4.1
July 2	13.0
July 3	21.9
July 5	6.8
July 6	15.6
July 8	0.5
July 9	9.4
July 10	18.2
July 12	3.1
July 13	12.0
July 14	20.9
July 16	5.8
July 17	14.6
July 18	23.5
July 20	8.4
July 21	17.3
July 23	2.1
July 24	11.0
July 25	19.9
July 27	4.8
July 28	13.7
July 29	22.5
July 31	7.4

RHEA

Date	Time
May 29	11.6
June 2	23.9
June 7	12.2
June 12	0.6
June 16	12.9
June 21	1.2
June 25	13.5
June 30	1.8
July 4	14.1
July 9	2.4
July 13	14.7
July 18	3.1
July 22	15.4
July 27	3.7
July 31	16.1

TETHYS

Date	Time
May 30	18.2
June 1	15.4
June 3	12.7
June 5	10.0
June 7	7.3
June 9	4.6
June 11	1.9
June 12	23.2
June 14	20.5
June 16	17.8
June 18	15.0
June 20	12.3
June 22	9.6
June 24	6.9
June 26	4.2
June 28	1.5
June 29	22.8
July 1	20.1
July 3	17.4
July 5	14.6
July 7	11.9
July 9	9.2
July 11	6.5
July 13	3.8
July 15	1.1
July 16	22.4
July 18	19.7
July 20	17.0
July 22	14.3
July 24	11.5
July 26	8.8
July 28	6.1
July 30	3.4

DIONE

Date	Time
May 31	19.5
June 3	13.2
June 6	6.8
June 9	0.5
June 11	18.1
June 14	11.8
June 17	5.4
June 19	23.1
June 22	16.7
June 25	10.3
June 28	4.0
June 30	21.6
July 3	15.3
July 6	8.9
July 9	2.6
July 11	20.2
July 14	13.9
July 17	7.5
July 20	1.2
July 22	18.8
July 25	12.5
July 28	6.1
July 30	23.8

TITAN

Date	Time
May 18	8.3
June 3	6.1
June 19	3.6
July 5	1.0
July 20	22.4

URANUS

TITANIA

Date	Time
May 29	6.9
June 7	0.1
June 15	17.3
June 24	10.5
July 3	3.8
July 11	21.1
July 20	14.3
July 29	7.6

OBERON

Date	Time
May 25	23.0
June 8	10.8
June 21	22.6
July 5	10.5
July 18	22.4

NEPTUNE

TRITON

Date	Time
May 28	2.3
June 2	23.4
June 8	20.5
June 14	17.6
June 20	14.7
June 26	11.8
July 2	9.0
July 8	6.1
July 14	3.2
July 20	0.3
July 25	21.5
July 31	18.6

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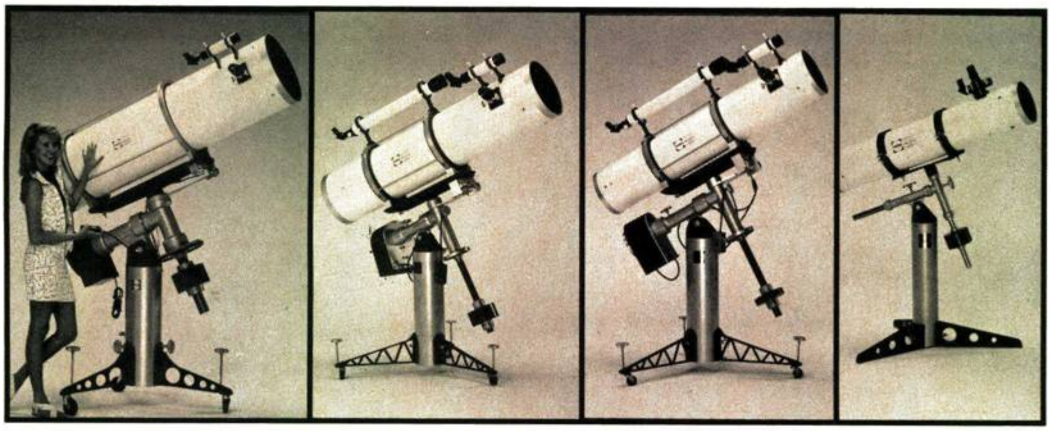

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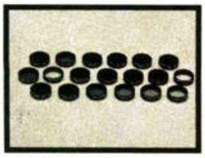

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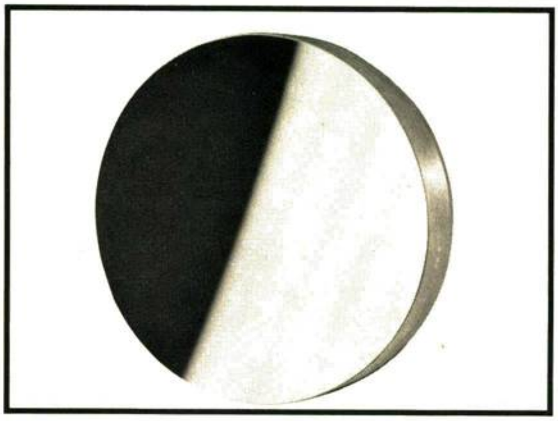

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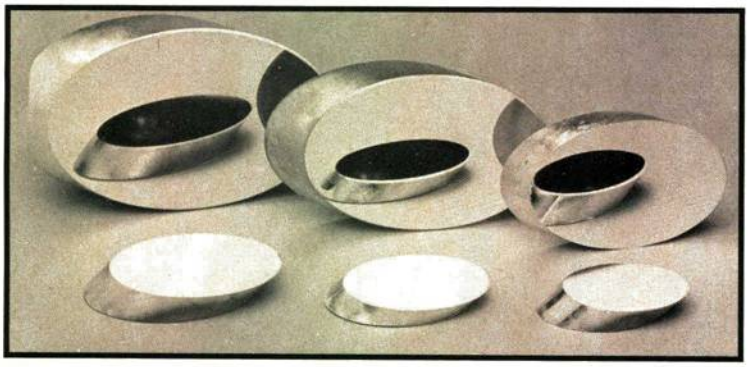

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You Can See a Star Flicker behind Saturn's Rings

Watch the star 28 Sagittarii pass behind Saturn and its rings in a most unusual occultation next month.

by Jeff Kanipe

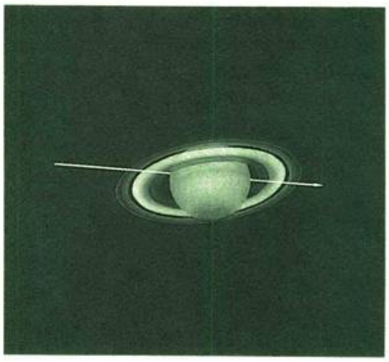
A rare planetary event will occur for Western Hemisphere observers during the morning of July 3. Beginning a little before 2 a.m. eastern daylight time, Saturn will occult, or pass in front of, 28 Sagittarii, a 5.8-magnitude star located just above the "Teapot handle" asterism in Sagittarius. For three-and-a-half hours the star's line of sight will cut prominently through Saturn's rings, duck behind the planet, and cut through the rings again. Observers with small telescopes will be able to see the star flicker as its light filters through varying thicknesses of ring material.

Among planetary occultations, an occultation of such a bright star by Saturn is nothing less than exceptional. The last Saturn occultation visible in the United States occurred in March 1984, when the ringed planet passed in front of a 9th-magnitude star in the constellation Libra. Unfortunately the faintness of the star relative to the rings made that occultation difficult to observe. In general, stars fainter than magnitude 8 are overwhelmed by the high surface brightness of Saturn's rings, which often washes out the star before the occultation even begins.

Stars as Probes

Observations of planetary occultations have been fruitful for astronomers over the past few decades. Being vanishingly small, a star makes an excellent point-source probe of a planet and the space around it. The way a star's brightness gradually changes as it passes behind a planet tells astronomers about the structure and transparency of the planet's atmosphere, the size of the planet, and the objects in orbit around it. Planetary occultations disclosed the presence of Uranus' rings in 1977 and ring arcs around Neptune in 1984.

Observations of Saturnian ring occultations made by both professional and amateur astronomers in 1917, 1939, 1957, 1960, and 1974 revealed the location of reported ring gaps and showed how the rings varied significantly in both density and structure. John E. Westfall, now the director of the Association of Lunar and Planetary Observers, noted many brightness fluctuations of a star that passed through the A and B rings during the 1957 occultation. Westfall reported that the star shone brightly through the Cassini division and through two divisions near the outer edge of the A ring.



28 SAGITTARII'S PATH takes it directly behind Saturn so that it cuts through both sides of the rings.

Getting Ready

The coming occultation will be a visual treat even in telescopes with apertures as small as 60mm. You should be able to see the star's light dim noticeably when the star moves behind a thick ring segment and brighten when it encounters a more tenuous segment. Ring gaps such as the Encke and Cassini divisions — where there are fewer rings — will manifest themselves when the star briefly rises to near maximum brightness.

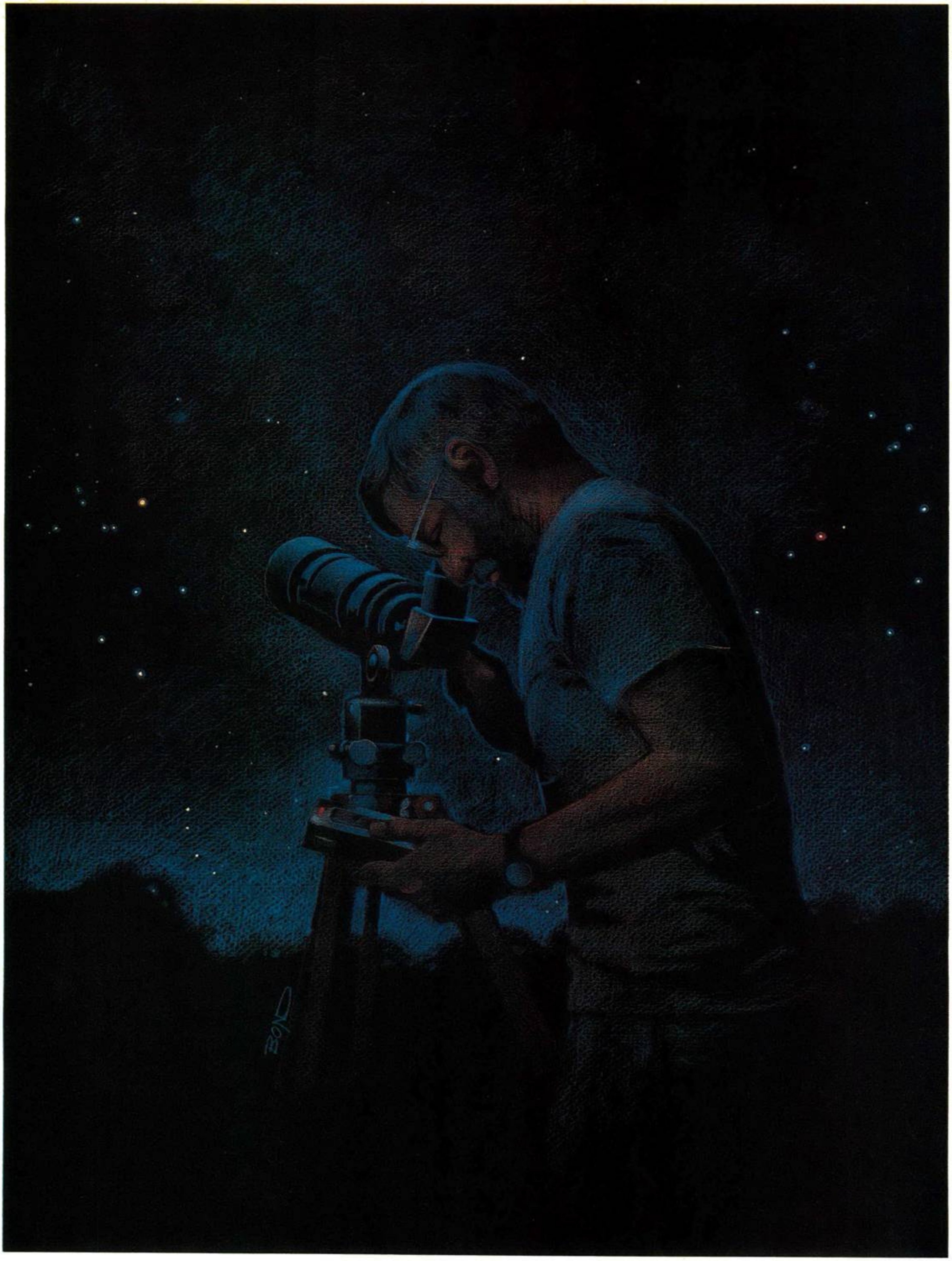
Observers with telescopes would do well to set up ahead of time and prepare an observing "run," or list of events to look for (some of these are given in the table on page 83). Though the occultation lasts for over three-and-a-half hours, you should expect to see the star's brightness change rather abruptly — sometimes within a matter of a few seconds — as the star passes "through" the rings. The star's disappearance behind the globe and its reappearance are also dramatic events easily missed if you're not watching at precisely the right moment. The best way to see all the action is to be prepared.

Telescopically you will need an image scale that allows you to monitor 28 Sagittarii's brightness fluctuations behind the different ring segments. (Binoculars, unfortunately, can't provide the image size needed to see the event in detail, though the star should be detectable away from the rings before and after the occultation.) Start out with moderate magnifications, about thirty to thirty-five times the aperture in inches. For a 6-inch telescope, this would be somewhere in the vicinity of 200x, for an 8-inch, 250x. If Saturn's image is steady, however, don't hesitate to try higher magnifications, as much as forty-five times the aperture.

If you own an equatorially mounted telescope with a clock drive, make sure the polar axis is aligned before the occultation. Good polar alignment allows you to observe at high power without the distraction of continually nudging the tube and readjusting the field.

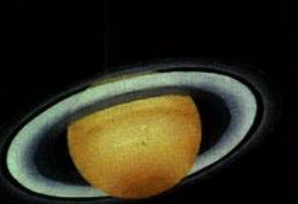
Observers who feel so inclined may wish to record their observations in some way. These records can be as simple as a series of sketches or as involved as a light curve (see sidebar on page 83).

You can also make a photographic record of the occultation if you follow

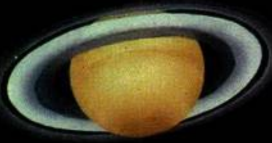


28 Sagittarii's Path behind Saturn

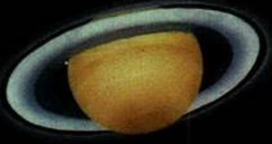
The star 28 Sagittarii may dim slightly as it encounters Saturn's F ring; two minutes later it abruptly fades as it enters the A ring.

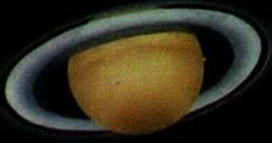


A dramatic increase in brightness occurs as the star shines through the Cassini division. Two minutes later it nearly vanishes behind the dense B ring.

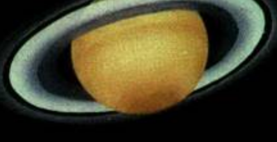


Just before it ducks behind Saturn's globe, 28 Sagittarii fades as its light passes through the upper layers of Saturn's atmosphere.

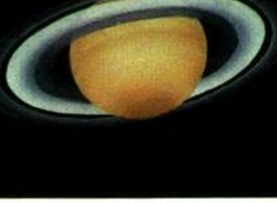




One hour and thirty-eight minutes after disappearing, 28 Sagittarii emerges from behind the planet and shines at full brightness.



Once again, the star glows brightly as its light passes through the Cassini division. Two minutes later it fades behind the A ring.



The star brightens briefly as it encounters the narrow Encke division near the outer edge of Ring A. Five minutes later the occultation is over.

a few steps. Because you will need a large image scale to record both the rings and the star, use eyepiece-projection (a telescope eyepiece coupled with the camera body).

Longer focal length, however, translates into a fainter image and longer exposures. There are two ways you can deal with this. If the seeing is good at your location and Saturn is relatively steady at medium to high magnifications, then you can use Kodak Technical Pan 2415. The very fine grain in this film allows you to use less magnification and enlarge the image when printing without serious loss of image quality.

Tech Pan is a slow film, though, and will require exposures of about 2 to 4 seconds at f/60. (Again, make sure your equatorial mount is tracking accurately!) If the seeing at your site is not very good — if Saturn's image is constantly boiling at medium to high magnifications — use a faster film, like Kodak's T-Max 400 or an ISO 400 color slide film. Exposures will need to be in the 1/2- to 1-second range at f/60.

If you have a video camera and the proper mount, you might try videotaping the occultation. The star should be bright enough for most cameras, and the entire event can be recorded on a single cassette. It probably would be a good idea to practice imaging Saturn or a similarly bright star *before* the occultation.

Times for the Occultation

The table on page 83 tells you the approximate times of important visual events occurring during the occultation. The predicted times are interpolations of times computed by Douglas Mink of the Harvard-Smithsonian Center for Astrophysics. Note that the times do not vary much over the entire region.

The occultation will be visible across the United States and most of the Western Hemisphere. Moreover, because of Saturn's distance and small angular extent on the sky, events will occur at nearly the same time throughout a time zone. The star's track, as seen from northern and southern extremes of the viewing area on Earth, will not vary at Saturn by more than about 1.25'' (which, by the way, closely represents the Earth's apparent diameter seen from Saturn!). Thus, from one observing station to the next, the time difference between a given event will be slight. In fact, the difference between identical events observed in the same time zone is only a matter of a minute or so depending on your location.

For example, at Washburn Observatory at Madison, Wisconsin, 28 Sagittarii will pass behind the A ring at 12:59:48 a.m. CDT. At McDonald Observatory near Fort Davis, Texas, this event occurs slightly over a minute and a half later at 1:01:27 CDT. Even when the distance between two viewing areas is great, such as between Massachusetts and Hawaii, the time varies between identical events by not more than seven or eight minutes.

Therefore, get ready to observe no later than 5:45 UT (1:45 a.m. EDT, 10:45 p.m. PDT). This is only fifteen minutes before 28 Sagittarii encounters the F ring (a narrow, diffuse ringlet lying just beyond the outermost A ring). In fact, it wouldn't hurt to be prepared even earlier than this: it would give you the opportunity to be relaxed and ready when the star first passes behind the rings (called immersion).

For observers on the East Coast of the United States, the F ring immersion occurs at 1:57 a.m. EDT, while on the West Coast it occurs at 11:00 p.m. PDT. Because of the F ring's narrow, tenuous nature, no dramatic change in brightness is likely to be seen. Nonetheless, this is a good time to begin looking closely for brightness variations. A noticeable dimming in the star's light should occur about two minutes later, when the star encounters the A ring.

East Coast observers will be hard pressed to see the late stages of the occultation — especially the star's emergence from the A ring — because the Sun will be only a few degrees below the eastern horizon. Midwesterners, too, may find it tough going during the F ring emersion, because the Sun will be only 9° below the horizon.

From Hawaii — perhaps one of the most convenient places to observe as far as time is concerned — the F ring immersion begins at 9:03 p.m., and the A ring immersion occurs about three minutes later. Observers on the east coast of Australia will have to wait for sunset, but they should be able to observe 28 Sagittarii's emersion from behind the globe at about 6:34 p.m.

We want to see your observations, whether they are sketches, photographs, or a light curve. Send your results to ASTRONOMY Magazine, 1027 North 7th Street, Milwaukee, WI 53233. All reports should include as much detail as possible, including the observer's location, time of observation, size and type of instrument used, sky conditions, and, for photographs, exposure information. We will report on your observations in a future issue. ☐

Occultation Timetable

Times are *approximate* for 32.5 degrees north latitude. In northeastern extremes of U.S. time zones, events occur up to 50 seconds earlier than the given time; in southwestern extremes of U.S. time zones, events occur about 50 seconds later. "NV" indicates that the event is not visible because of impending sunrise; * indicates that the event may be difficult to see for the same reason.

Events	EDT	CDT	MDT	PDT	Hawaii
Immersion					
F ring	1:57 a.m.	12:58 a.m.	11:58 p.m.	11:00 p.m.	9:03 p.m.
Outer A ring	1:59 a.m.	1:00 a.m.	12:01 a.m.	11:01 p.m.	9:06 p.m.
Outer Encke gap	2:02 a.m.	1:03 a.m.	12:03 a.m.	11:03 p.m.	9:08 p.m.
Inner Cassini division	2:12 a.m.	1:13 a.m.	12:13 a.m.	11:13 p.m.	9:18 p.m.
Outer B ring	2:14 a.m.	1:15 a.m.	12:15 a.m.	11:15 p.m.	9:20 p.m.
Mid-C ring	2:40 a.m.	1:41 a.m.	12:41 a.m.	11:41 p.m.	9:47 p.m.
Globe	2:49 a.m.	1:50 a.m.	12:50 a.m.	11:50 p.m.	9:54 p.m.
Emersion					
Globe	4:27 a.m.	3:28 a.m.	2:27 a.m.	1:28 a.m.	11:32 p.m.
Mid-C ring	4:37 a.m.	3:37 a.m.	2:37 a.m.	1:37 a.m.	11:41 p.m.
Inner B ring	4:50 a.m.	3:50 a.m.	2:50 a.m.	1:50 a.m.	11:54 p.m.
Inner Cassini division	5:10 a.m.	4:11 a.m.	3:10 a.m.	2:10 a.m.	12:14 a.m.
Inner A ring	5:13 a.m.*	4:13 a.m.	3:12 a.m.	2:12 a.m.	12:17 a.m.
Outer Encke gap	NV	4:22 a.m.	3:21 a.m.	2:21 a.m.	12:26 a.m.
F ring	NV	4:27 a.m.*	3:26 a.m.	2:26 a.m.	12:30 a.m.

Making a Light Curve from Your Observations

If you have access to a digital stopwatch and a short-wave radio or a time and weather receiver (inexpensive models of the latter cost $39.95 at Radio Shack), you can make a light curve of the July 3 Saturn occultation. A light curve shows how the star varies in brightness over time, which is directly related to the ring's structure.

One of the most accurate means of creating a light curve involves dictating your observations into a portable cassette recorder while recording the continuous time beats from WWV, the time station out of Fort Collins, Colorado. Just tune your short-wave radio to 5.0, 10.0, or 15.0 MHz; Canadian observers can tune into CHU from Ottawa at 3.35, 7.35, and 14.65 MHz.

The stopwatch comes in handy when the WWV or CHU signals fade (as they sometimes do). When this happens, start your stopwatch and keep track of the time until the signal returns.

Determine the longitude and latitude of your observing site to within 10 or 20 seconds (less than half a mile) as well as your elevation above sea level to within a 10 feet. This information can be determined by carefully measuring your location on a U.S. Geological Survey topographical map of your area. These maps can be found at the local library or a map store.

It is most important that you respond quickly to brightness changes and other events by calling out your observations almost as they occur. You should be able to note an event within half a second of its occurrence, which is about as efficient as the eye-brain-vocal relay system gets.

As the star passes behind the rings, call out your observations as clearly and in as few words as possible. To keep the nonessential verbiage down and the reporting efficiency up, develop a code that allows you to gauge unexpected brightness fluctuations.

For example, you might say "peak" when the star seems to be very bright in the rings. If at some point it seems even brighter than the previous peak, say "peak 1". As the star fades you might say "F". If it fades still further, say "F1", then "F2", etc. When it becomes semivisible say "weak", and when the star vanishes, say "zip".

Once the star reappears, say "B" for brightening, and for subsequent brightenings say "B1", "B2", etc. If the star appears to flicker in brightness say "Flick." If you decide your observation is in error, say "cancel" and then quickly revise it.

As soon as possible, plot your observations on regular graph paper. Divide the horizontal axis into equal time increments spanning the occultation and divide the vertical axis into varying brightness scales that correspond to your observations. As the tape plays back, note each observation as a dot in the appropriate time position. When you have plotted all your observations, you will see at once where the tenuous and dense regions of the rings are, as well as the gaps. Your graph will essentially represent a cross section of ring structure. ☐

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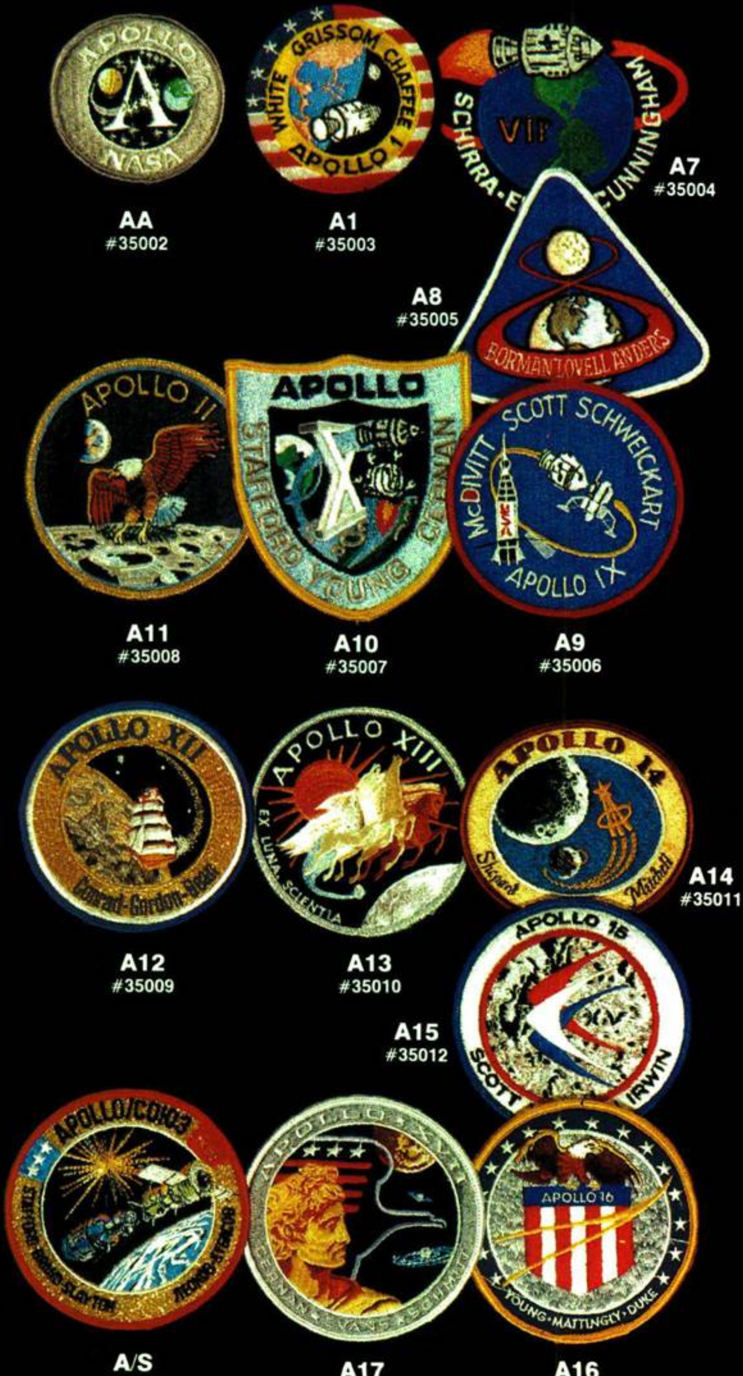
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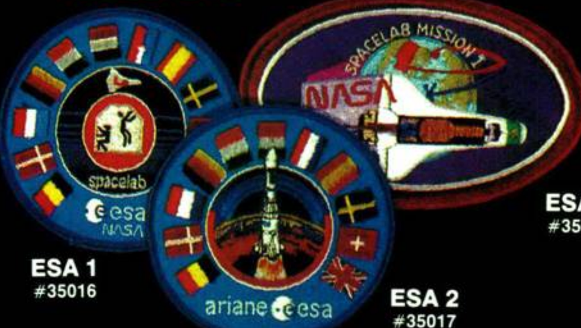
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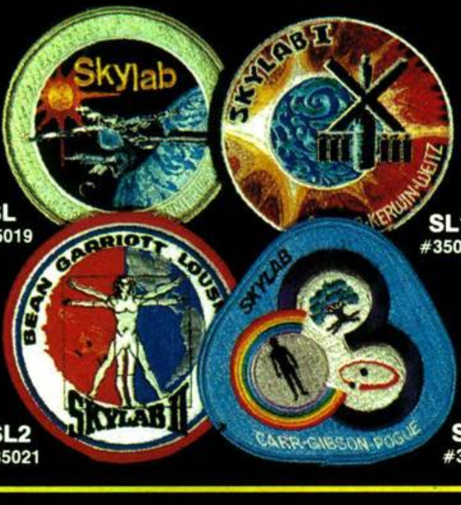
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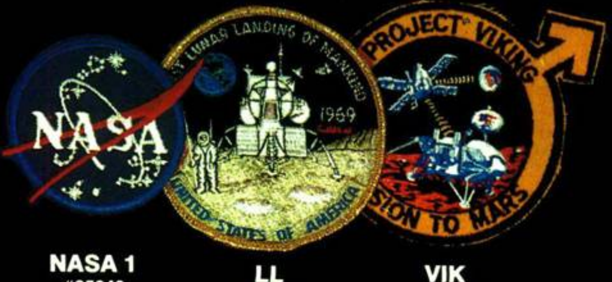
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The dust clouds lying in front of bright objects are among the most exotic and most challenging sights for deep-sky observers.

by David Higgins

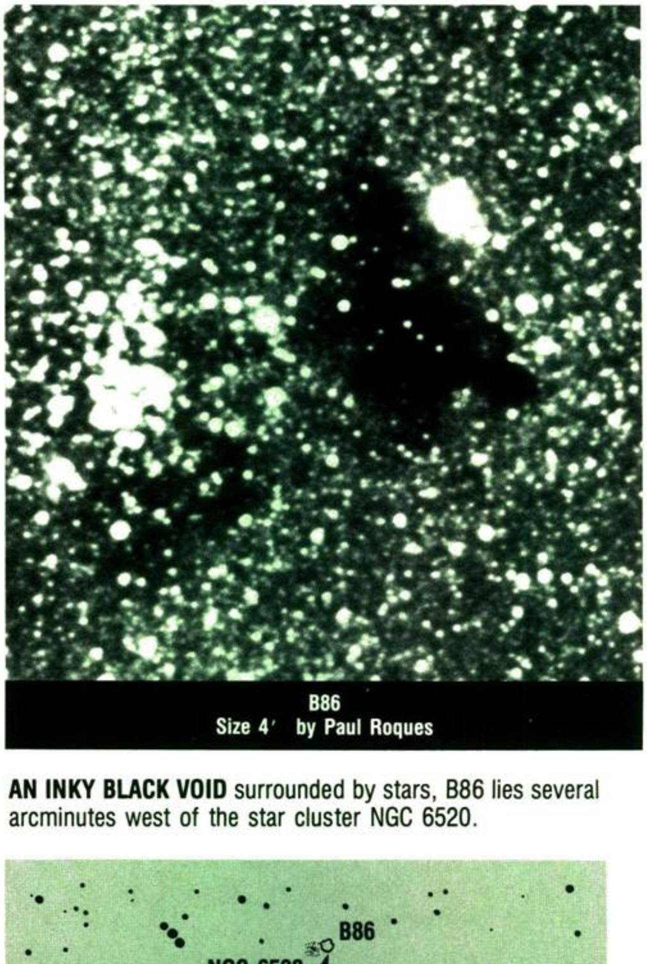
Galaxies are full of dust and our Galaxy is no exception. You can see some of this dust by standing outside some night this summer and gazing up at the Milky Way's glowing band of light. When you view the Milky Way from a dark sky, you'll see small lines and clumps of darkness winding through its graceful arch. Although they appear like holes in the Milky Way, these dark patches are actually dust clouds lying in front of the Galaxy's plane. These objects, called dark nebulae, are clouds made of minute, dark dust grains about the size of those in cigarette smoke. Rather than producing or reflecting starlight like bright nebulae, countless particles in each dark nebula absorb light, blocking our view of bright objects that lie beyond the nebulae.

Dark nebulae run the gamut from large and dense to small and tenuous; some are easily observed and others quite elusive. The visibility of a dark nebula depends on its opacity and the density of stars surrounding it. On a dark summer night, several dark nebulae are easily visible in large telescopes and provide a challenge for small scopes. These objects provide a stunning contrast to bright nebulae.

The most stunning dark nebula in small telescopes is **Barnard 92**, named after Edward Emerson Barnard, an astronomer who discovered and catalogued 370 dark nebulae around the turn of the century. B92 is easy to find because it floats in front of the bright, rich starcloud M24 in northern Sagittarius. To find B92, start by locating M24, which is visible to the naked eye as a small, misty cloud of light. Aim your telescope at M24 and sweep around it for a moment, soaking up the great numbers of faint stars. Now move your telescope to the northern edge of the cloud. Using a low-power eyepiece, you'll see two small dark nebulae. The westernmost and larger of the two is B92.

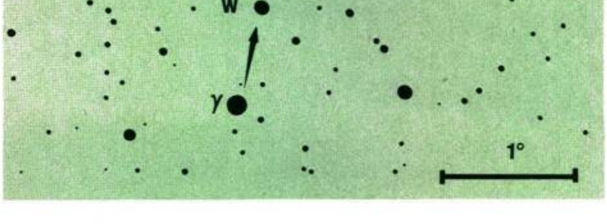
In a 6-inch telescope you'll recognize B92 as a crescent-shaped area devoid of the stars that surround it. Low-power views will show a rich array of stars ringing the outer edge of the field, nicely framing the stark nebula. This aptly demonstrates why early astronomers believed dark nebulae were holes or voids in the Galaxy. A 12th-magnitude star is visible in the nebula and has the appearance of a solitary star basking in empty space. In reality, however, the star is a foreground object.

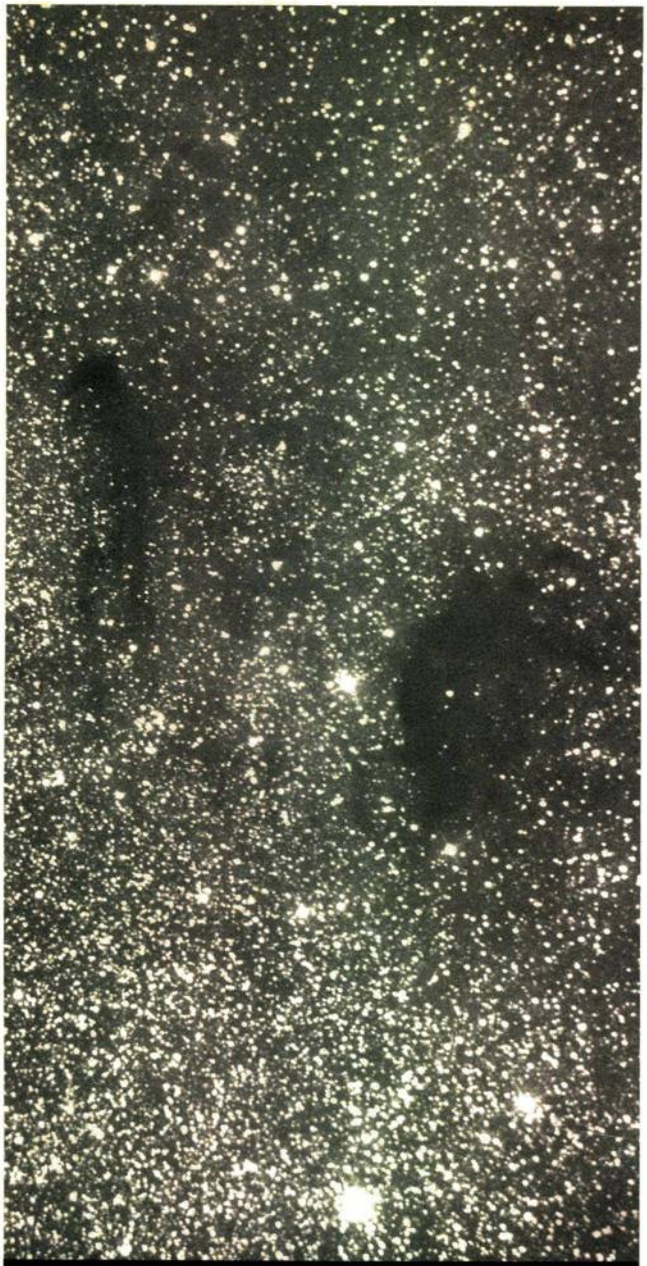
A 12-inch scope at moderate power shows B92 as a dark patch measuring 12′ by 6′ with its long axis



B86
Size 4′ by Paul Roques

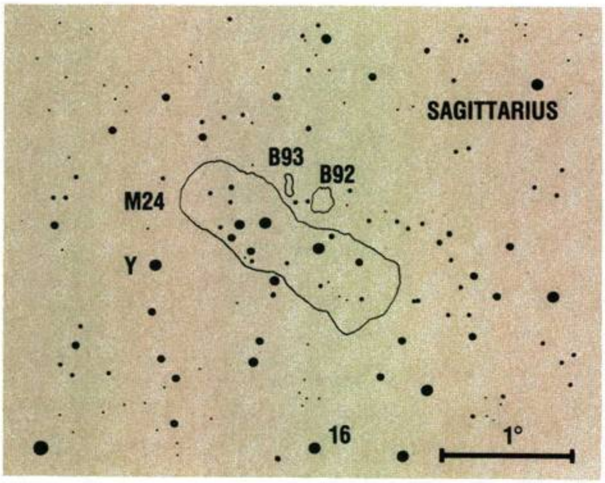
AN INKY BLACK VOID surrounded by stars, B86 lies several arcminutes west of the star cluster NGC 6520.





B92 and B93
Sizes 12′ by 6′ and 12′ by 2′ by Martin C. Germano

DARK NEBULAE B92 and B93 block light from the bright star cloud M24 in star-rich northern Sagittarius.



aligned approximately north-south. The nebula's shape is basically oval, but with averted vision two small extensions are visible on its southern end and one is visible on its northern end. The extensions loop into the surrounding starfield, covering 2′ or 3′ before being swallowed up by stars.

The central star is easily visible with direct vision, and the nebula is bordered by a magnitude 9.4 star on its southern tip and a magnitude 8.4 star on its eastern edge. With averted vision a few faint specks in the nebula flash in and out, eluding direct visibility.

Large backyard telescopes show B92 more prominently because they show many fainter stars around the nebula's edge. With a 17.5-inch scope at high magnification, B92 has a "feathery" appearance because very faint stars are visible in jagged patterns around its edges. This makes it appear like a three-dimensional, black cloud floating in space. The nebula's eastern edge is sharply defined, while its western edge is not as well defined and gradually fades into the stellar background. A 17.5-inch scope also reveals five extremely faint stars within the nebula, in addition to the 12th-magnitude central star.

If you observe B92 with low power, you may notice another dark nebula in the same field to the northeast. Scan 20′ northeast of B92 with high power to locate **B93,** which measures 12′ x 2′. Although it isn't as opaque or sharply-defined as B92, B93 is also an easy target. B93 is comet-shaped; it has a circular head on its northern end and a tail that flows south over 15′. About 7′ south ot the head the tail splits in two and forms two distinct dark areas. The northern half of B93 is easily visible in small scopes, but the double tail is difficult or even invisible unless the night is exceptionally dark.

One of the keys to observing dark nebulae like B93 is to slowly sweep across the field using as wide a field as possible. Proper magnification is a must. Large nebulae and nebulae with low opacity both require low magnification to stand out from the stellar background. Small nebulae and high-opacity nebulae can withstand high magnification for close inspection; in fact some appear much better at high powers.

High contrast is also important for observing dark nebulae. You can maximize contrast in two ways. Always observe dark nebulae under a very dark sky. Reduce scattered light in your telescope by baffling the tube, painting the inside of the tube flat black, and keeping the mirror clean.

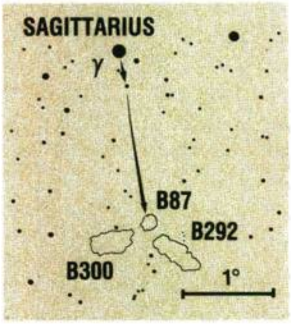
The star chart you use is equally as important as your telescope. Most modern atlases do not show dark nebulae, but two atlases that do are Antonin Becvar's *Atlas of the Heavens* and volume II of *Uranometria 2000.0*, which covers the southern sky.

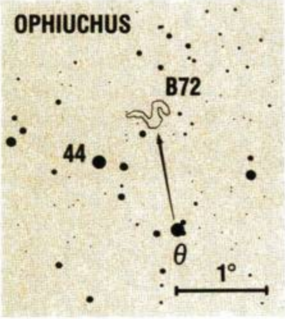
The summer sky holds other challenging examples of dark nebulae, some of which are more easily visible than others. Another object in Sagittarius, **B86**, is relatively easy to find because it lies 4° south of the Lagoon Nebula and 2.5° north of Gamma Sagittarii. B86 measures 4′ across, is wedge-shaped, and stands out well from the exceedingly rich Milky Way background. The bright open cluster NGC 6520 lies just 5′ east of B86. The two objects are visible together in practically any field of view, even at moderately high magnification.

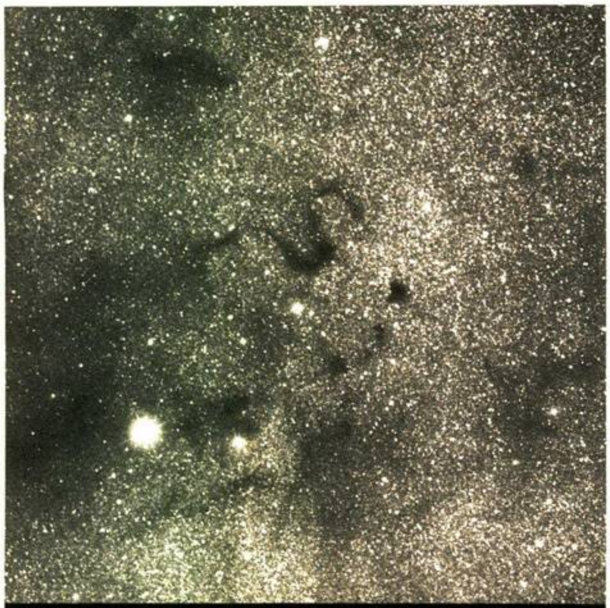
Small scopes show B86 as a square void immediately south of a magnitude-6.9, orange star. Another orange, 7th-magnitude star lies on the nebula's north-

B87
Size 12′ by Martin C. Germano

A BIRD IN PROFILE, elusive B87 (above) earns its nickname, the Parrot's Head Nebula. Barnard's Snake Nebula (below) carves an S-shaped hole in the sky.







B72
Size 4′ by Paul Roques

Dusty Dark Nebulae

Object	R.A. (2000.0)	Dec.	Size	Uranometria
B72	17h23.5m	−23°38′	4′	II: 337, 338
B86	18h02.7m	−27°50′	4′	II: 339
B87	18h04.3m	−32°30′	12′	II: 377
B92	18h15.5m	−18°11′	12′ by 6′	II: 339
B93	18h16.9m	−18°04′	12′ by 2′	II: 339

Object: Designation in Barnard catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Size:** Diameter in arcminutes. **Uranometria:** Chart on which object appears in *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi.

western edge. Unlike B92, B86 has edges that gradually fade into the surrounding background of stars. The nebula's high opacity alone makes it stand out well.

Another dark nebula in southern Sagittarius is **B87**. This round nebula lies 2° south and a few arcminutes west of Gamma Sagittarii. B87 is far more challenging than B92 for small telescopes because its center is filled with myriad stars. The result is a circular dark nebula 12′ across with a low opacity. B87 has a curved extension to the east, and its eastern side appears slightly darker than its western side. Two larger, less opaque dark nebulae, B292 and B300, lie southwest and southeast of B87. To Barnard and other early observers, the three nebulae together resembled a winged bird. Because of this, B87 is nicknamed the Parrot's Head Nebula. An 8th-magnitude star lies just east of the nebula's center, marking the bird s eye.

One of Barnard's most famous nebulae is **B72**, an elusive object located in Ophiuchus. Because of its S-shape, B72 has been given the nicknames "S Nebula" and "Snake Nebula." Its unique shape makes B72 a sought-after object for amateur observers. To find B72, aim your telescope at Theta Ophiuchi and sweep 1.5° north-northeast. (The nebula can also be found by moving less than a degree northwest of 44 Ophiuchi.) If the sky is exceptionally dark, a low-power field will show a thin, winding dark lane that covers nearly 30′ and is oriented east-west. The width of the winding dark lane varies between 2′ and 3′ throughout its path. With averted vision you should see that the dark lane forms an "S."

Observing dark nebulae will challenge you and your telescope on different levels. B92, B93, and B86 are high-contrast nebulae so viewing them under moderately dark skies is straightforward. On particularly dark nights, try to resolve and count individual stars within these nebulae to test the acuity of your eye. The lower-opacity nebulae, B87 and B72, are much more difficult to observe. Simply seeing them or tracing their shapes is a challenge. Whichever challenge you take, you're certain to discover an entirely new type of observing when you aim your scope at the dusty blotches called dark nebulae. ☐

David Higgins frequently observes dark nebulae with his 24-inch telescope in Oklahoma. He is central coordinator of the National Deep Sky Observers Society and a contributing editor to Deep Sky.

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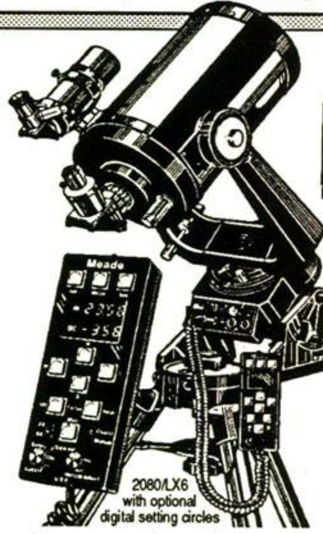

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Build a Backyard Observatory

You and your telescope deserve an observatory, especially one that's this easy to build.

by Steven Chomniak

If you love the stars, you really need a backyard observatory. And contrary to what you might think, building an observatory is simple, straightforward, and reasonably inexpensive. If you've built something before — a doghouse, an outside deck, or a garden shed — you're already familiar with the terms and techniques for building an observatory.

If you have no carpentry experience, you should check out a few "how to" books from the local library and peruse them before starting to build an observatory. Once you're familiar with the terms and procedures, all you need to build the observatory are a few spare weekends and a few hundred dollars. In return for your effort, you'll eliminate the hassle of backyard astronomy and keep observing *fun*.

An observatory does three things that help you get more from observing. First, it protects your telescope and accessories from the elements, which increases their useful lifetimes. Second, its walls protect you from the elements. Third, it lets you quickly and efficiently begin and end observing sessions.

This last point is the most important. By permanently housing your scope in a fixed position, you eliminate the repetitive chore of polar aligning your scope every time you want to observe. You'll soon discover that you do a lot more observing when you can simply walk outside, open the observatory, and start to observe.

Thinking Design

Okay, so you want to build an observatory. What's the next step? Don't run out into the backyard and start nailing boards together. First, determine the type and size of structure that will suit you and your scope best. You know what you want to get from the building, so you need to plan an observatory that meets your objectives. You want a building that protects your telescope from weather, can be locked up safely for security, and is comfortable to work in. Naturally you'll want to keep the cost of materials and construction as low as possible too.

The simplest method for meeting all of these goals is to build a roll-off roof observatory. It is much simpler and less expensive to construct than a dome, and it has the added advantage of letting you see most of the sky as you observe. There is a drawback to this type of observatory, however. A roll-off roof structure provides less protection from wind, dew, and stray light. But the positive side of this is that in a roll-off roof observatory you feel part of the sky and stars; in a dome you see only a small piece of the sky at one time and feel as if you're missing something. (Some types of observing, like meteor watching and spotting satellites, can't be done effectively inside a dome.) And because it resembles a garden shed, the roll-off roof observatory is less likely to be a target for vandalism than a domed observatory.

First, come up with a plan tailored to your telescope and tastes. After finalizing this, you need to clear the legal hurdles. In nearly all communities what you can build in your yard is strictly governed by a building code. Check with your local municipality and find out what must be done to begin construction. Also, check your deed to see if any restrictions exist there. You'll probably need to obtain a building permit, and you may even have to approve the plans with the local building inspector or city engineer. It's a bit of a hassle, but it must be done. The local inspector could order you to tear down an unapproved structure, plus you could receive a whopping fine.

Shed with a Roll-Off Roof

My observatory consists of a pier firmly secured in the ground surrounded by a garden shed with a roof I can slide off. Once you have a little background, through experience or reading, this type is simple to build over the course of a few weekends. (For background reading, see Readings and Resources on page 112.)

Provide adequate room in your observatory; too much is better than too little. (There's nothing worse than spending night after night in a cramped, uncomfortable space without sufficient room for moving yourself and the telescope around.) For my 8-inch SCT I chose a structure that measured 9 feet by 8 feet by 7 feet with an equal-size track on which the roof sits while I'm observing.

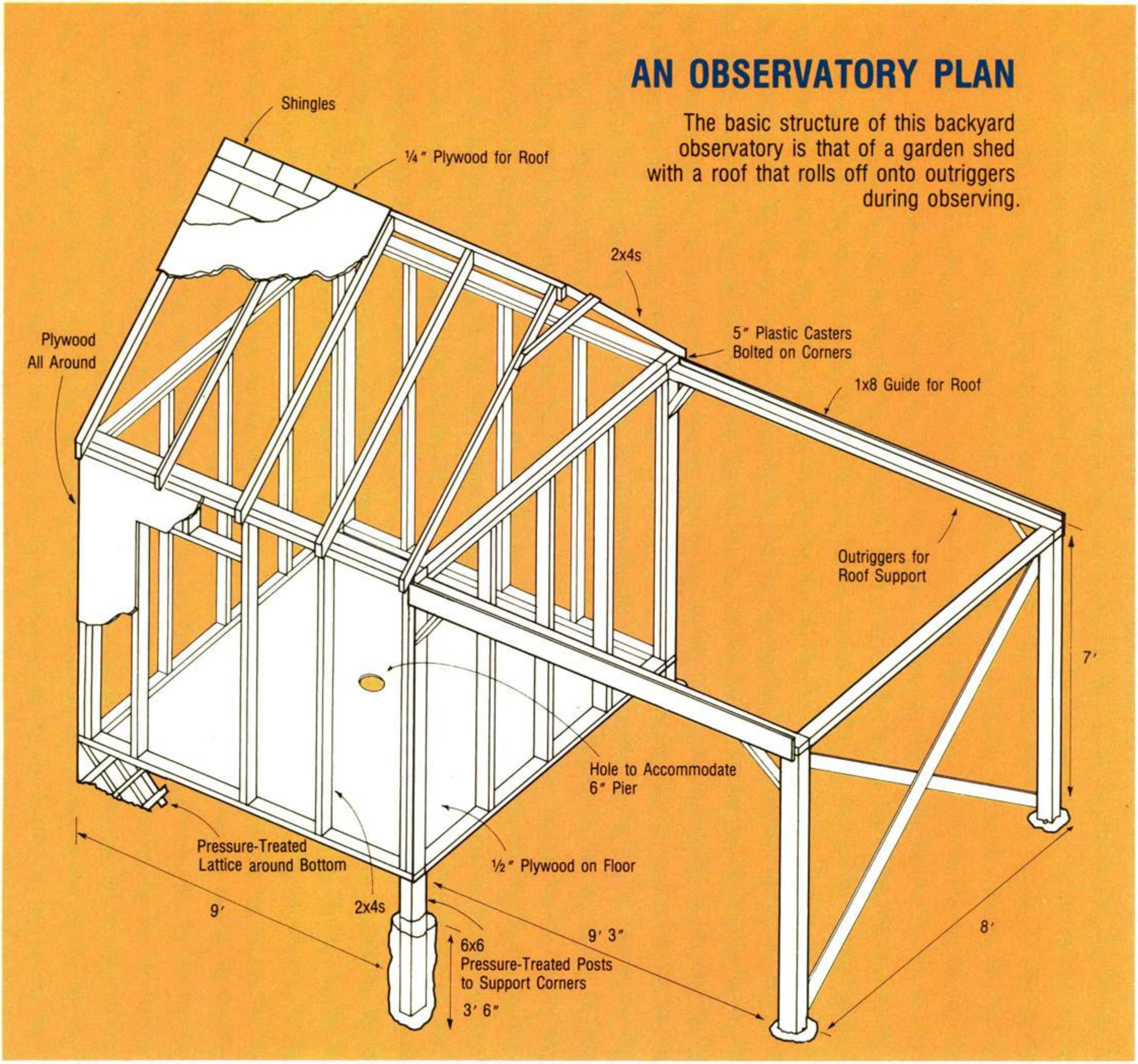
Estimate the dimensions of the shed you'll need. Set up your telescope, swing it to look at all parts of the sky, and measure the clearances. Also think about other things that will be kept in the observatory. Space for books, charts, and eyepieces can be considerable, and you may want to add a shelf or a small table to accommodate them. If you have a Newtonian telescope, you'll need extra space because of the tube length and the way the mount works. The telescope's tube can swing well away from the central pier on two sides, depending on where you're aiming it. Remember that careful planning early saves lots of headaches later on.

Constructing Your Observatory

The construction procedure is relatively straightforward. First, you'll dig holes and sink six upright poles outlining the shed. Next come wooden girders and floor joists attached to the sunken poles. The joists provide support for a floor and, in turn, walls and a roof. You then sink a central pier for the telescope and fill all of the pipes and pier with sand, gravel, and concrete. The walls, roof, and track system for supporting the roof are all pure and simple carpentry at its best.

AN OBSERVATORY PLAN

The basic structure of this backyard observatory is that of a garden shed with a roof that rolls off onto outriggers during observing.



Shingles
¼″ Plywood for Roof
2x4s
Plywood All Around
5″ Plastic Casters Bolted on Corners
1x8 Guide for Roof
Outriggers for Roof Support
7′
Hole to Accommodate 6″ Pier
Pressure-Treated Lattice around Bottom
½″ Plywood on Floor
9′
2x4s
9′ 3″
8′
6x6 Pressure-Treated Posts to Support Corners
3′ 6″

The last stages are adding a few amenities like a dead-bolt lock, drain pipes, and indoor-outdoor carpeting. You can also add electricity for operating the telescope's drive by running a line to the observatory and wiring a socket. (For more information on this, consult a book on electrical wiring.) The last step is to paint the observatory an attractive color, preferably one that matches the color of your house.

Before you begin construction, check the ground by eye to make sure it's reasonably level. Clear the site of woody vegetation, rocks, and other debris. If you have doubts about the soil's ability to drain water, dig a test pit a few feet deep nearby and see how moist the soil is. Try not to build the observatory on a site with poor drainage.

Laying the Foundation

After figuring out where the building will go and which way it will face, you're ready to lay the foundation lines. Four stakes will mark the four corners of the foundation. Measure one long wall of the building and drive two stakes in the ground to mark the corners.

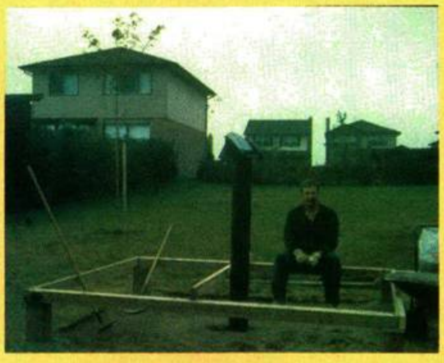
Using a large carpenter's square, measure off the remaining sides of the structure and sink a stake at each corner. To check the squareness of the layout, measure both diagonals and make sure they're equal. If not, go back and carefully lay them again using the right angle. Once you've marked the corners, you can begin building.

You're now ready to install the footings. Dig holes to accommodate the footings and mix concrete according to the instructions. I recommend using six 6x6 8-foot pressure-treated wooden posts, one in each corner and two halfway between the corners on the building's long sides. The posts should be long enough to provide reliable support for the building's weight and reach one foot below the frost line. Check with the local city engineer for the deepest possible frost line in your area. Make sure that the posts all extend 6 inches above the ground.

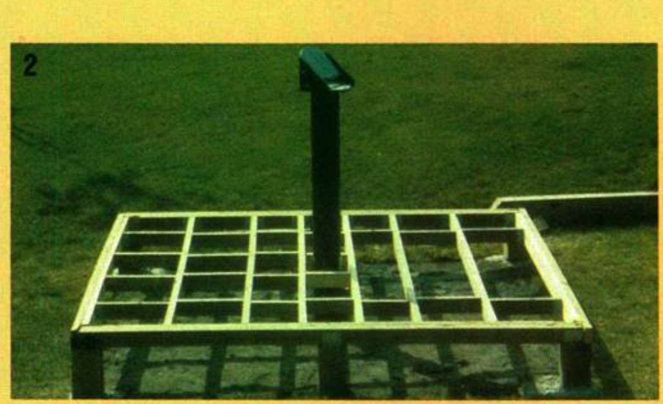
Now connect the posts, forming a base on which the floor and walls will be supported. Wooden girders consisting of three 2x4s nailed together form

RAISING AN OBSERVATORY

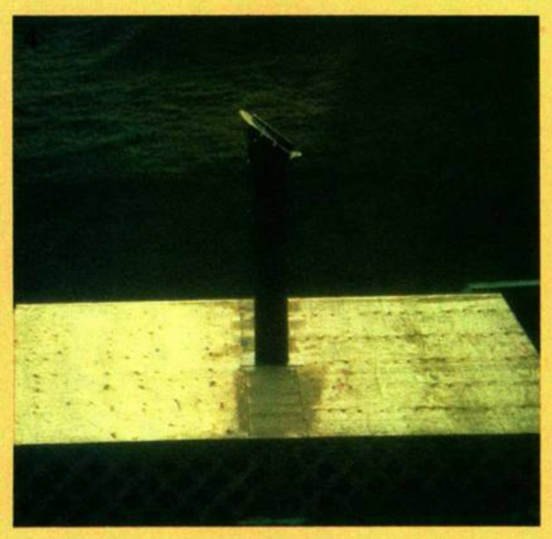
If you have some construction experience, building your own observatory with a roll-off roof is much easier than you think. After you have a tight plan, the construction takes as little as two or three weekends.



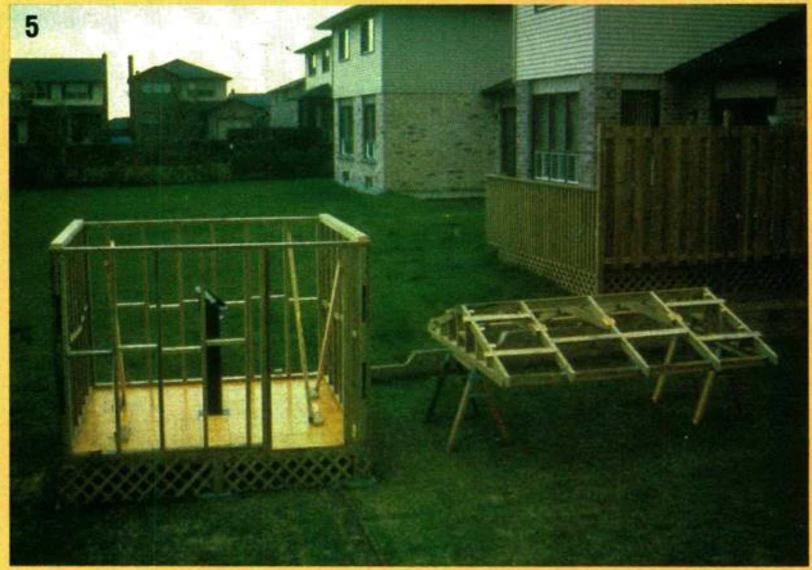
After clearing the ground, sink four corner posts and position a central pier for the telescope. Three layers of 2x4s nailed to the posts outline the observatory floor.



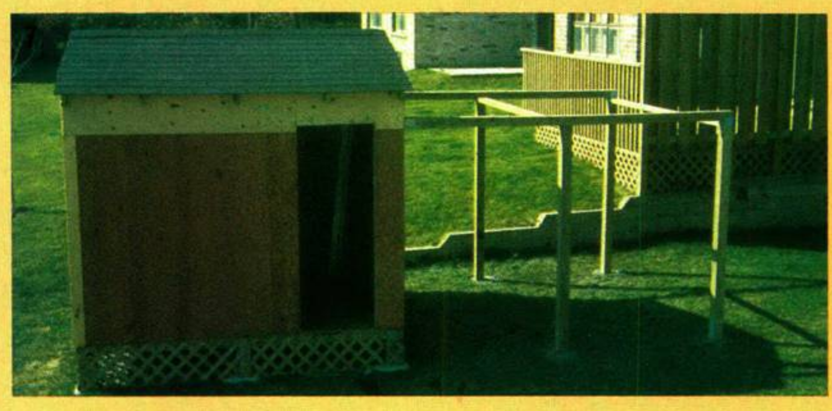
Attach joists made of 2x4s. These support the floor.



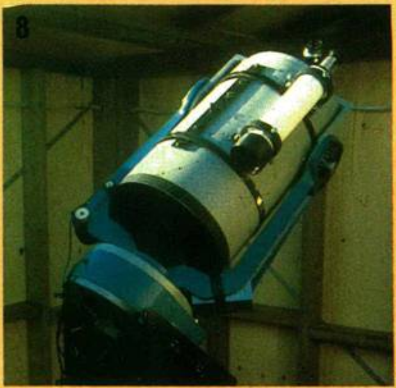
Create a floor using ¾″ plywood and attach pressure-treated lattice to the base of the structure.



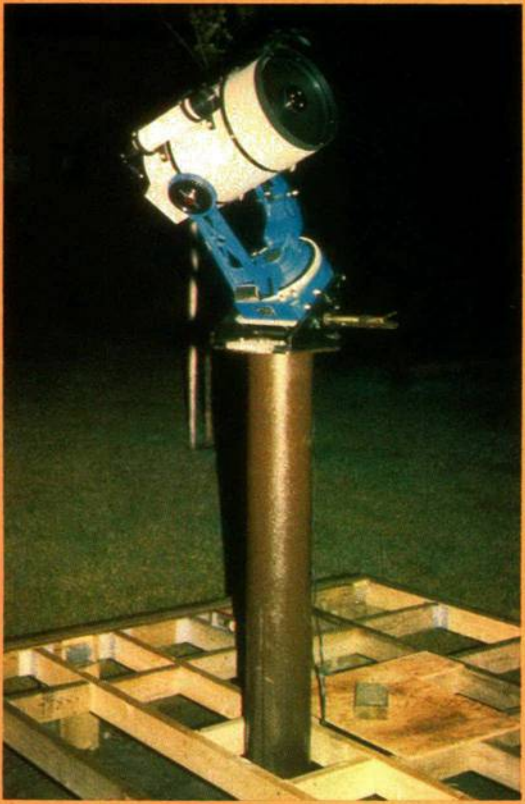
Build a wall frame using 2x4s and assemble the frame for the roof.



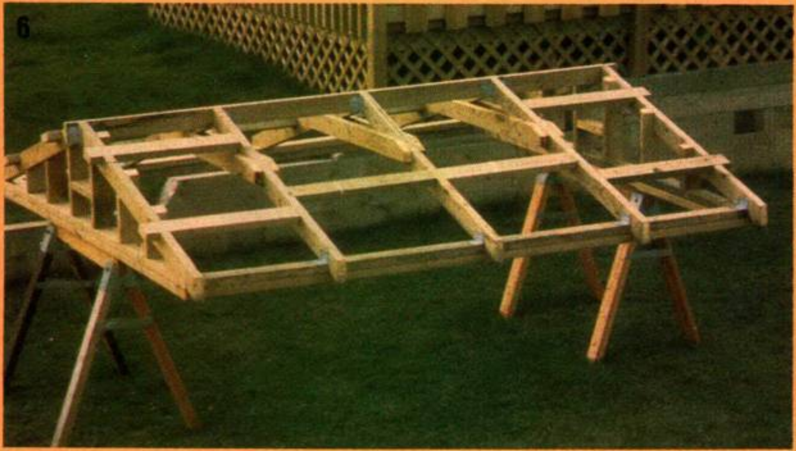
Plywood sheeting attached to the frame creates the structure's walls and roof. Shingles nailed firmly on top help prevent water damage.



The telescope sits inside a roofed building. However, the roof needs a track system.



Make sure the pier is aligned with the north celestial pole, then set it in concrete.



The roof frame is a gable design joined by a central top board.

The final stage of construction is to build outriggers, a system of poles and 2x4s to support the roof when it's rolled off the shed.

this base. As you put the girders in place, make sure again that everything is square. If the girders don't form a rectangle, you'll have real problems putting the walls up correctly.

I used a 6-inch-diameter pipe 9 feet long for the telescope's pier. The size you'll want to use depends on the frost line at your site and where you want the top of the pier. I dug a hole 4 feet deep, inserted the pipe, and filled it with sand. At night I returned and filled the surrounding hole with concrete, carefully polar aligning the pier with Polaris before the cement had time to set.

The Joy of Carpentry

Now we've got a telescope pier inside a bare foundation, and it's time for pure carpentry. Floor joists will provide the main support for flooring. I placed 2x4s 12 inches apart across the girders and fastened them with 2¼-inch galvanized nails. On the ends I installed double joists to provide enough support for the walls. These consisted of two 2x4s with a small block placed at each end and nailed together.

Next comes the floor itself. I used two sheets of ¾-inch by 4-foot by 8-foot plywood and simply nailed them to the floor joists. Laying the flooring at a right angle to the joists is a good idea to ensure durability. Don't let the floor touch the telescope pier; leave at least an inch of space. I then sprayed the floor with two coats of liquid plastic (available at hardware stores) to protect it from water and dirt carried in from the outside. Someday I'll add indoor-outdoor carpeting, a nicety you might want right off the bat.

The walls come next. Wall frames consist of a bottom sole plate, studs placed 16 inches apart, and a double top plate. The sole plate is simply a perimeter of lumber on the floor to mount wall supports on. The double top plate is the same thing used for the roof but consists of two layers of 2x4s instead of one. The studs are vertical 2x4s that serve as a frame for mounting the wall boards.

Start by placing long, straight 2x4s flat on the floor around the outside edge to create a sole plate. This sole plate extends all the way around the outside edge of the observatory except where you want to install a door. Because the sole plate and double top plate are identical in dimensions, you can make the double top plate a duplicate of the sole plate. Lay it aside until you install the corner posts and studs.

After you have a sole plate nailed on to the floor, add corner posts. The corner posts are studs made of three

OBSERVATORY PARTS LIST

4	6x6 by 8′ pressure-treated posts
4	4x4 by 10′ pressure-treated posts
2	4′ by 8′ sheets of ½″ spruce plywood
12	4′ by 8′ sheets of ¼″ spruce plywood
3	4′ by 8′ sheets of pressure-treated lattice
2	1x12 by 8′ pine trim
8	1x4 by 8′ pine trim
14	1x2 by 2′ pine trim
36	2x4 by 12′ studs
16	metal strip braces
6	bags of 25-year shingles
12	bags of premixed concrete
6	bags of ¾″ stones
1	gallon of brown stain or paint
1	quart of stain for pine trim
4	5″ heavy-duty plastic casters
1	doorknob
1	deadbolt lock
1	6″ pipe, 9′ or 10′ long for pier
4	boxes of 2¼″ galvanized nails
4	boxes of 1″ galvanized spiral nails
1	box of ¾″ aluminum roofing nails
	liquid plastic
	*gutters
	*indoor-outdoor carpeting
	*electrical cable, switch, circuit breaker, and connectors
	*red and white light bulbs and sockets

*optional

Note: Dimensions and amounts will change depending on the size of your telescope and observatory.

Tools required: wood saw, ax, carpenter's level, 25-foot steel tape, measure, tri-square, carpenter's square, shovel, wheelbarrow for mixing concrete, mixing tool for concrete, mixing tool for paint, paint brush, chalk line, string or twine, plumb bob, utility knife, stepladder, curved claw hammer, screwdrivers, C-clamps, pliers, two sawhorses or variant. **Optional:** saber saw with medium wood blade, circular saw with combination blade, power drill.

2x4s laid atop one another. After nailing the 2x4s together, attach them to the sole plate with metal strip braces. Add three more corner posts. Now cut more studs that exactly match the corner posts in length and nail them to the sole plate, leaving 16 inches between the center of each stud. It's a good idea to brace the studs horizontally with small sections of 2x4 placed midway between the floor and roof. As you install the studs, leave a hole in the frame for a door. Later you'll add a door, doorknob, and lock in this space. When you've finished erecting all of the studs, you can attach the double top plate. Reinforce all of the framework with metal strip braces and you'll have a finished wall frame.

Raising the wall is typically a two- or three-person job, so you'll have to enlist family or friends to help. Cut a piece of plywood sheeting to the proper size for one of the long walls. As one or two of you raise it squarely into position, drive nails through the sheet at several places along each stud and into the floor and roof supports. Don't pound the nails all the way in, however, until you're certain the walls are square.

When this is finished, repeat the process with the other three sections of wall sheeting. Now you can add a door in the hole you left and install the accompanying hardware according to the manufacturer's instructions. I added a doorknob and a dead-bolt lock for extra security. You can also add paneling in a variety of finishes to the outside of the walls. Simply attach it with small finishing nails and make sure it extends over the base all the way up to the roof.

Raising the Roof

Building and raising the roof is one of the trickiest parts of observatory construction. You can choose from several varieties of roofs, but I suggest using a simple gable roof. The gable roof has two equal pitches that rise to a single central ridge. I built the roof on two sawhorses set up in the backyard and began by nailing two 2x4s together to form the base of the roof.

Construct a frame for the roof by laying 2x4s on top of one another, matching the double top plate exactly. Once that's completed, attach rafters, which are small sections of 2x4s angling up to the central ridge board. The rafters are attached to the frame and ridge board with metal strip plates. You'll need to figure out the angle you want to achieve and the boards necessary to brace the gable accurately. It's a good idea to cross-brace the rafters with little splints of wood.

When the roof frame is done, it should look like a flattened A-frame. I attached sheets of ¼-inch plywood for the roof itself and layered asphalt shingles on top of the plywood. To complete the roof, turn it over and install four 5-inch casters, one in each corner.

I had four people lift the roof and set it down carefully on top of the double top plate. As they held it in place, I nailed 1x8 boards along three sides of the observatory, which act as guides so the roof cannot slide off sideways or away from the track support. Next, I tackled the problem of supporting the roof when it is rolled off for observing.

Outriggers, boards, and posts for supporting the roof when the observatory is opened are easier to install than they appear. The outriggers connect to one side of the building and consist of four posts sunk into the ground and two tracks to roll the roof on to. I carefully measured the positions of the posts, dug the holes, placed the posts in the ground, and filled the surrounding space with concrete. Before the concrete completely hardened, I braced the posts with 2x4s placed horizontally between them and added two 2x4s for tracks on which the casters roll when I move the roof. In addition, nail 2x4s that extend upward along the sides of the tracks to keep the wheels on the tracks when you move the roof.

After finishing the outriggers, you're done with the basic structure. However, you might want to add a few finishing touches for the sake of convenience and appearance. I added a gutter and drain pipe to the roof, hoping that efficient water run-off would prolong the useful life of the structure's wood. I coated exposed wood with plastic sealant. To protect the wood and help with scattered light problems, paint the exterior white or a light color and the interior walls of your observatory a dark color except for the floor, which you should paint white. This will help you see what you're doing in the observatory but minimizes reflected light.

Now that you've built your own observatory, you'll experience backyard astronomy in a totally new way. You won't believe how natural it feels to walk outside and start absorbing starlight right away. I think you'll find, as I did, that having a backyard observatory is so much of a revelation that you'll find yourself trying to win converts at the next astronomy club meeting! ☐

Steven Chomniak lives in Oshawa, Ontario, where he spends a great deal of time in his backyard observatory enjoying the night sky.

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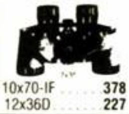

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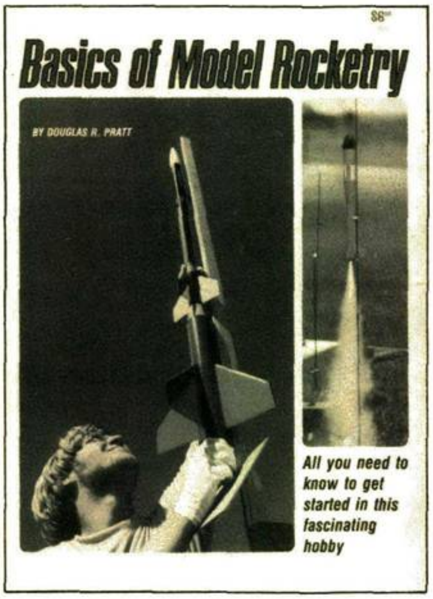
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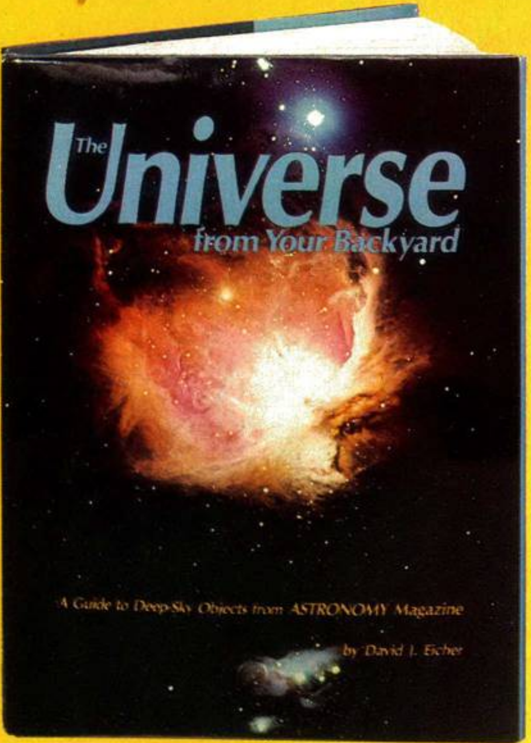
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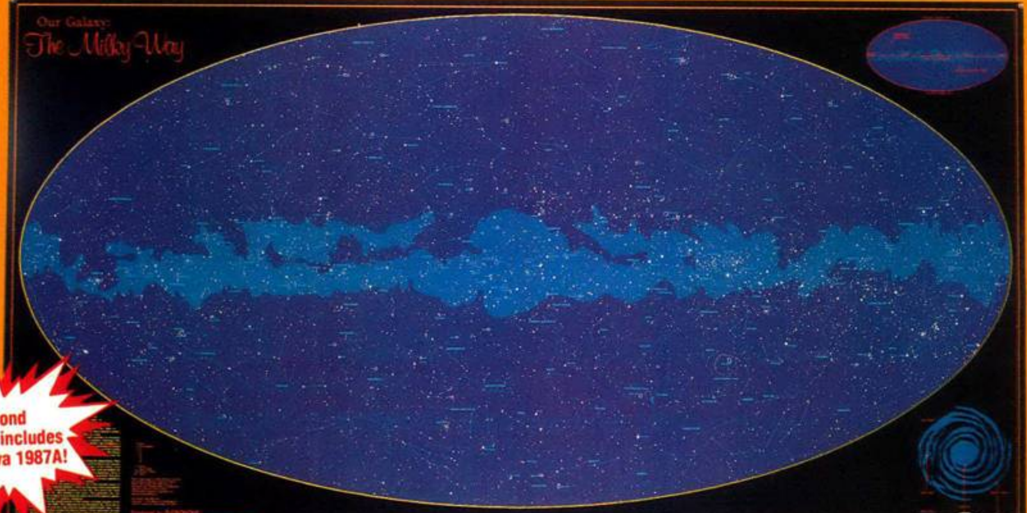

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MARCH 7'S PARTIAL SOLAR ECLIPSE

Clear skies over much of the nation greeted observers of a partial eclipse of the Sun on the morning of March 7, 1989. Observers set up telescopes and loaded cameras with film to see the Moon's disk cover up to 80 percent of the Sun.

The event was visible west of a line passing through northern Michigan, Chicago, central Missouri, eastern Oklahoma, and central Texas. Observers in the Midwest and Plains states saw a tiny sliver disappear from the Sun. However, eclipse watchers in Alaska saw 80 percent of the Sun's disk covered and West Coast sungazers saw between 40 and 60 percent.

Californians seemed especially excited by the eclipse. Jacques Guertin of the Peninsula Astronomical Society set up his telescope for eclipse photography at Walnut Creek, California, despite the fact that skies over the San Francisco Bay area had been overcast that morning.

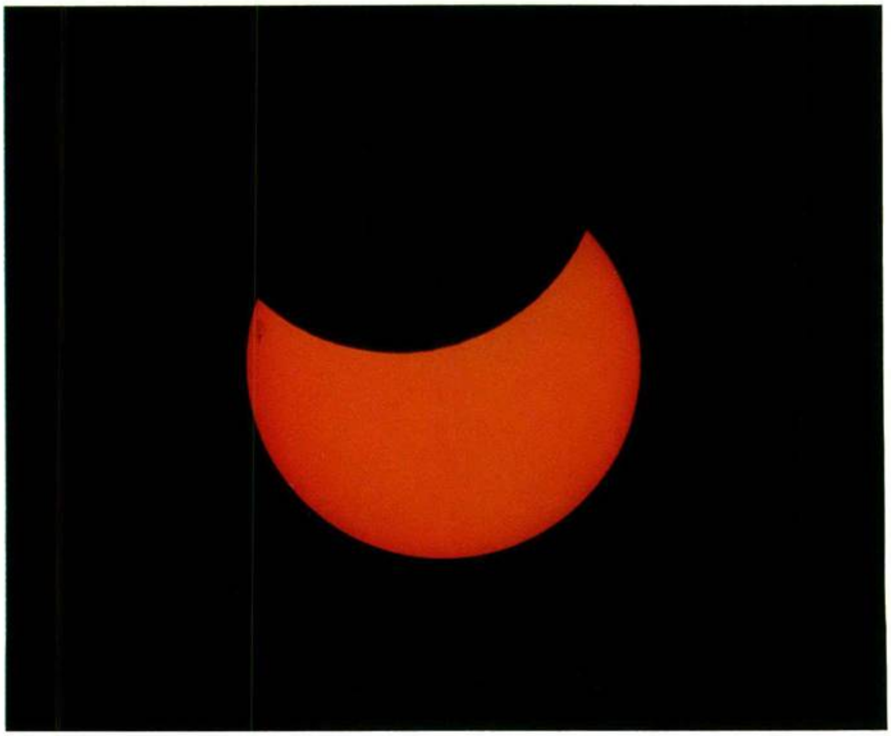
"I was lucky," reported Guertin. "The clouds began to break up ten minutes before first contact, which occurred at 8:53 a.m. PST. By mid-eclipse (9:52 a.m.), all the clouds had dissipated. We saw a beautiful solar disk that was 46-percent eclipsed. Last contact occurred at 10:54 a.m., and exactly one hour later it clouded up again and rained heavily that afternoon. It seemed nature treated Bay area observers well by parting the veil of clouds specifically for the eclipse."

Graced with clear skies, observers in southern California fared somewhat better. Using safe Sun viewing as a theme, Father Ronald Royer showed the eclipse to 340 schoolchildren and many adult onlookers at the St. Pancratius Rectory in Lakewood. Royer used his 12.5-inch f/6 Newtonian to project a 14"-diameter image of the Sun onto his observatory's inner wall. The Sun was safely visible throughout the eclipse and could be viewed by a dozen people or more at a time.

"As each group passed by," explained Royer, "I showed them the eclipsed Sun and gave a short talk on safe methods for viewing the Sun's disk. I had told the kids not to stare at the Sun directly, and to drive this point home I placed a piece of paper at the exit pupil of the eyepiece and watched as it burst into flames. There is no better way of explaining to kids, or adults, the dangers of viewing the Sun."

Many observers farther east viewed a

HUNDREDS WATCHED THE ECLIPSE projected onto an observatory wall at the St. Pancratius Rectory in Lakewood, California. Photo by Ronald E. Royer.



A PARTIAL ECLIPSE of the Sun that occurred on March 7 was visible in the western United States. Jacques Guertin snapped this photo using a 700mm f/8 lens, Kodachrome 25 film, and a 1/125-second exposure.

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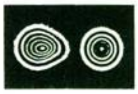

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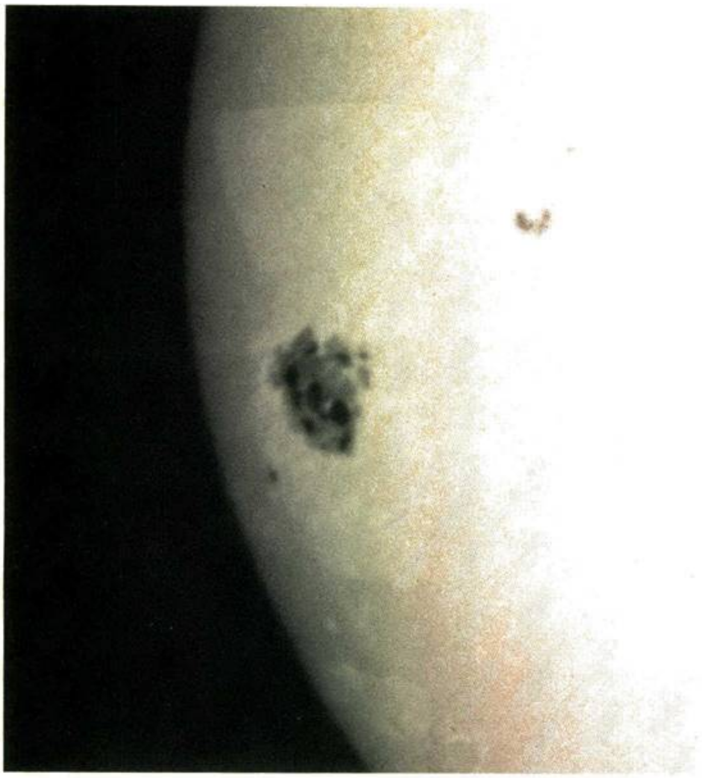
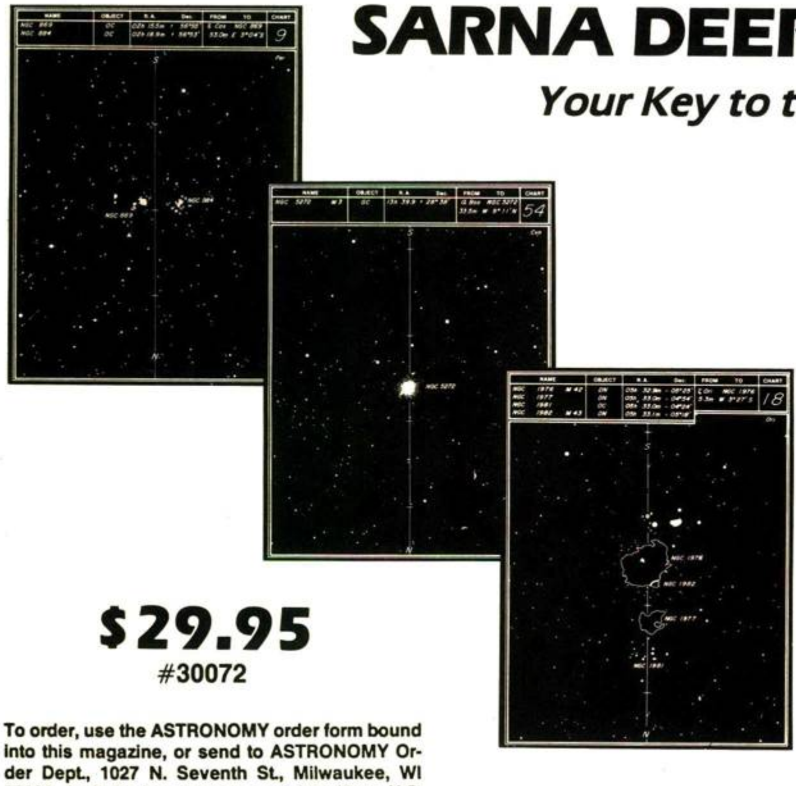


AN ENORMOUS SUNSPOT group rotated onto the solar disk on the same day the eclipse occurred. Photo by Andrew W. Steinbrecher.

less-eclipsed Sun. Michael J. Hutchinson of Longmont, Colorado, saw the eclipse begin at 10:28 a.m. MST. "Partial cloud cover hampered the eclipse for the first few minutes," Hutchinson reported. "However, by 10:55 a.m. the clouds were gone, and I watched the eclipse unabated. It peaked around 11:17 a.m. with about 30 percent coverage."

In Walworth, Wisconsin, high school student Curt S. Otto reported observing the slim eclipse using a 4¼-inch Astroscan telescope and projection onto paper. "Our science teacher took us out to see the eclipse," explained Otto, "and set up his scope behind the high school. We saw the eclipse begin at 12:39 a.m. and watched as the Moon slowly passed in front of the Sun. It was the first time I have seen an eclipse, and I came away thinking it was worth the effort. Although it wasn't a total eclipse, I was struck by the silent beauty of such an awesome spectacle." — *David J. Eicher* ☐



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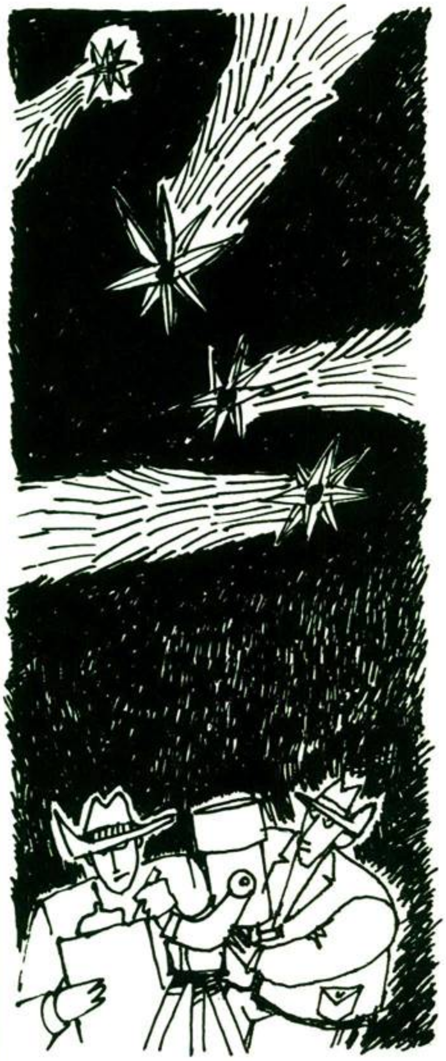

Nineteen eight-seven was a busy year for amateur comet observers. Throughout the year a total of sixteen comets were visible in 12-inch telescopes, and as many as four comets could be seen each night. A rush of discoveries between August and October, however, meant that in early November nine or possibly even ten comets would be visible in one night.

On November 12, 1987, I had the perfect opportunity to try for ten comets in one night, three more than I had ever observed at one time.

My friend James Athanasou and I traveled thirty miles to escape the lights of Perth in western Australia. But when we arrived at our site, we discovered that trees to the southwest would obscure at least two comets. We moved to a nearby railway line and found an ideal location with a perfect eastern horizon. We quickly unpacked the telescope and began a search for our first comet, Levy (1987y).

But by the time it was dark enough to identify the starfield surrounding the comet, the comet had slipped below the horizon. It was just a little too close to the Sun to observe from our latitude.

So we turned our attention to Comet McNaught (1987b1), which was already getting low. It too was very close to the Sun, but it was situated well south among the bright stars of Scorpius. At magnitude 7.4 and 3.5′ in diameter, McNaught was easy to observe despite the still-lingering twilight.

Interesting as Comet McNaught was, we hurried on as our third comet, Bradfield (1987s), rapidly approached the horizon. Like McNaught, Comet Bradfield was easy to locate. At magnitude 5.3, it was the brightest comet we would observe that night. Also, because it was well away from the twilight glow, its 1.5° tail was impressive even in binoculars. Several streamers were visible, although they were not as obvious as last month when the comet was higher in the sky. We closely examined the tail and found that the angle between the ion and dust tails had increased and that the tails could be seen as separate objects about 0.8° from the coma.

We expected the next two comets to be the most difficult: periodic comets Brooks 2 (1987n) and Klemola (1987i). Situated only a few degrees apart, these comets were receding and therefore fading rapidly.

To better adapt our eyes to the dark, we covered our heads with black hoods and sat talking for over half an hour before I aimed the telescope at Brooks 2. At first nothing was visible, but then I suddenly caught a glimpse of a faint patch of light. Comet Brooks 2! I recorded its brightness (magnitude 13.3) and its size (2′) and then surrendered the telescope to James.

While he was observing, we discussed our chances with Klemola. Predicted to be half a magnitude fainter than Brooks 2, Klemola would be very difficult.

I scanned the area for ten minutes, but nothing was visible. After fifteen minutes I was about ready to give up. Then I saw a small patch of light. There it was. It was so *faint* that even with averted vision I could only hold it for twenty seconds.

Once again I let James take over at the telescope. We determined Klemola's magnitude to be 13.8, by far the faintest we had ever seen through a 12-inch scope. But we couldn't stop. We needed to move on to the next comet, Schwassmann-Wachmann 1.

Schwassmann-Wachmann 1 is an unusual periodic comet with a nearly circular oribt between Jupiter and Saturn. Normally around magnitude 18, at irregular intervals it undergoes outbursts in brightness of up to eight magnitudes. But tonight the comet was not visible. That was our second failure of the evening.

At 11:30 p.m. we began searching for Comet Borrelly (1987p). Another periodic comet, Borrelly was making a very favorable return. Because the comet was situated almost directly overhead, we had some trouble aiming the telescope at it, but eventually we succeeded. A tail-less ball of light glowing at magnitude 7.6, Borrelly had a small, bright central condensation some 3′ across surrounded by a faint outer coma 9′ across.

Borrelly was our last evening comet. We went home for a short nap and returned two hours later to complete our comet hunt. The first comet we aimed for was Comet Wilson (1986l). Despite the bright Moon that had risen, the comet was easily visible. However, at magnitude 11.4, it was only a shadow of the spectacle it had been earlier in the year.

Our next target was Rudenko (1987u). A fast-moving comet that had only recently become visible from the Southern Hemisphere, Rudenko appeared nearly twice as large as Comet McNaught. No tail was visible, but that wasn't surprising because the sky was already quite bright with the approaching dawn.

We had seen seven comets so far, and we still had a chance at one more. In a race against the approaching dawn I began to hunt down the final comet on our list, periodic comet Schwassmann-Wachmann 2 (1986h). Predicted to be around 12th magnitude in the twilight sky, it would not be easy to observe.

More by luck than skill I landed on the correct area almost immediately. Changing to 115x magnification, I began to examine the region carefully, and there it was — a small, diffuse patch of light. I made way for James and he saw it easily as well. At magnitude 11.7 it was almost half a magnitude brighter than predicted.

We had found our eighth comet of the night. Though we hadn't been able to see all ten comets we had hoped for, we had beaten our own record. And with the frequency of comet discoveries, we probably won't have long to wait before we get another chance at ten comets in one night. — *M. L. Clark* ☐

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PUTTING THE PIECES TOGETHER

Creation, The Story of the Origin and Evolution of the Universe by Barry Parker, (Plenum Press, 1988), ISBN 0-306-42952-7, hardcover, 297 pages, $22.95.

(Telephone rings)

Congressperson Frelb: Hello, Frelb here.

Dr. Diggs: Good morning Mr. Frelb, this is Dr. Diggs. I would like you to appropriate $50 million to allow us to blast out a chamber three miles below ground.

Frelb: Well, Dr. Diggs, that sounds like a lot of money for a hole.

Diggs: We are going to fill it with pure water!

Frelb: (smiling) Must be a big room. Distilled water sells for 89 cents a gallon at my local grocery store. What happens next?

Diggs: We watch it for a year and it tells us how the universe formed.

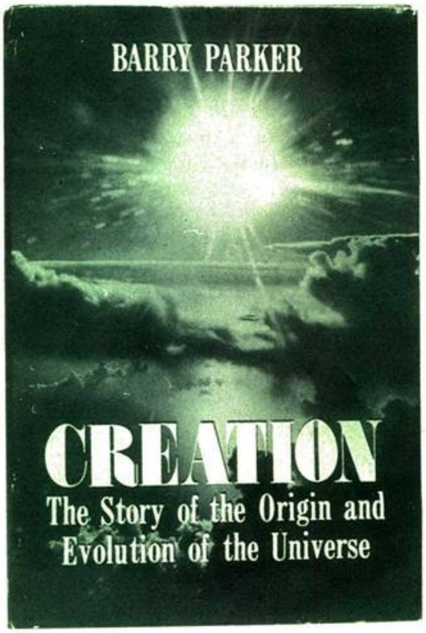
Frelb: HA HA HA HA HA HA (click).

Dr. Diggs should have sent Congressperson Frelb a copy of *Creation* by Barry Parker to soften the blow of his request. Like the ancient Greeks who traveled to smoke-filled caves to consult the oracles about their futures, modern physicists and astronomers must travel to water-filled caves to determine the past and future of our universe. In the case of Dr. Diggs' cave, physicists are looking for a single proton to decay. If they can catch just one in the act, they'll know a little more about how stable matter is in the universe.

Although this may seem like an outlandish research topic to Congressperson Frelb, understanding the stability of matter in the universe is one of the most important issues in physics today. In Barry Parker's delightful book, we explore this and other important issues by watching the universe grow and evolve from the first milliseconds after the Big Bang to the formation of the first nuclei, from galaxy formation to the development of life on Earth. Moreover, we see how the scientists who made these discoveries arrived at their conclusions. The glimpses Parker gives into their personal and professional lives adds dimension to their contributions.

Most scientists, we learn from Parker's book, find the solutions to the big puzzles by looking for smaller bits and pieces that are more easily solved. Edwin Hubble was a perfect example. In the opening chapter, "Discovery of the Expanding Universe," Parker shows us how Hubble, building on work by the American astronomer Vesto Slipher, discovered a velocity-distance relation for the "spiral nebulae." His conclusion that these objects were galaxies, hence the universe was expanding, stunned astronomers worldwide.

Of course there were many scientists before Hubble who tried to put the puzzle pieces together, which Parker relates in the chapter "Cosmology of the Mind." Often, though, their work took unexpected turns. Einstein, for example, discovered that his description of the universe predicted that it expands. He was so appalled at the prospect that he introduced a fudge factor to do away with expansion. Other theorists, working to fathom the fate of the expanding universe, reached three different predictions: the universe will expand forever, the universe will stop expanding at some very distant time in the future, or the universe will stop expanding and begin to contract at some time in the future. Although the outcome remains to be seen, one of the goals of the *Hubble Space Telescope* is to try and answer this part of the universal puzzle.



Parker also introduces us to one of the greatest ideas our civilization has produced: All the different kinds of forces we experience were once unified as a single force in the extreme conditions of the young universe. It takes Grand Unified

Theories (GUTs) to describe the earliest times of the universe.

The GUTs also predict some presently observable conditions in today's universe. For example, in chapter seven Parker discusses Alan Guth's inflation theory, which describes the universe between 10^{-36} and 10^{-34} seconds after the Big Bang. Inflation predicts the formation of matter in the universe (an easily verifiable prediction) and tells us how matter came into existence. Many a theory has ended up in the wastebasket for failing to produce matter!

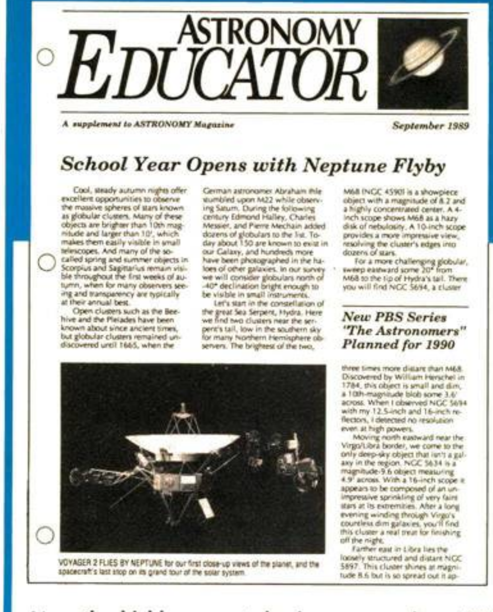
Parker also delves into the theories that have failed to tell us where matter has gone — specifically antimatter. Matter-prediction theories estimate that equal amounts of matter and antimatter should have promptly annihilated each other in the early universe, leaving us with an energy-filled universe.

Parker's chapter "Mystery of the Cosmic Mirror" leads us out of this dilemma by exploring the capable work of physicists Andrei Sakharov and Sheldon Glashow, to name a few. Along the way we get a healthy dose of particle physics and find out why Dr. Diggs' cave is so important: The good, testable theories that predict the formation of more matter than antimatter also predict that the proton has a finite lifetime of 10^{31} years. Hence, though it may be long-lived, there is no such thing as stable matter.

Parker wraps up *Creation* with a not unexpected chapter describing how raw materials might have produced life. Unfortunately, "The Emergence of Life" was, for me, the weakest chapter. A subject that fills many shelves in libraries is difficult, if not impossible, to condense adequately into fourteen pages. Parker's failure to introduce any of the colorful scientists in this field further dilutes the impact this chapter should have had.

Creation also contains a number of errors that should have caught the attention of the science editors. The value for the galactic year (the time it takes the Sun to orbit the center of our Galaxy) is wrong in two places in the book; in fact, it is off by a factor of 1,000. The time of the recombination event, when the plasma turned into a neutral gas, is given different values at several different places in the book. And I must quibble with the statement (page 266) that literally every atom in a human's body was formed in a star. We are about 98 percent water. Water, by number, is two-thirds hydrogen. So only one-third of our bodies came from stars. (However, no one can argue about the extreme importance of that one-third!)

ATTENTION SCIENCE TEACHERS!



ASTRONOMY EDUCATOR

A supplement to ASTRONOMY Magazine

September 1989

School Year Opens with Neptune Flyby

Cool, steady autumn nights offer excellent opportunities to observe the massive spheres of stars known as globular clusters. Many of these objects are brighter than 10th magnitude and larger than 10', which makes them easily visible in small telescopes. And many of the so-called spring and summer objects in Scorpius and Sagittarius remain visible throughout the first weeks of autumn, when for many observers seeing and transparency are typically at their annual best.

Open clusters such as the Beehive and the Pleiades have been known about since ancient times, but globular clusters remained undiscovered until 1665, when the German astronomer Abraham Ihle stumbled upon M22 while observing Saturn. During the following century Edmond Halley, Charles Messier, and Pierre Mechain added dozens of globulars to the list. Today about 150 are known to exist in our Galaxy, and hundreds more have been photographed in the haloes of other galaxies. In our survey we will consider globulars north of -40° declination bright enough to be visible in small instruments.

Let's start in the constellation of the great Sea Serpent, Hydra. Here we find two clusters near the serpent's tail, low in the southern sky for many Northern Hemisphere observers. The brightest of the two, M68 (NGC 4590) is a showpiece object with a magnitude of 8.2 and a highly concentrated center. A 4-inch scope shows M68 as a hazy disk of nebulosity. A 10-inch scope provides a more impressive view, resolving the cluster's edges into dozens of stars.

For a more challenging globular, sweep eastward some 20° from M68 to the tip of Hydra's tail. There you will find NGC 5694, a cluster three times more distant than M68. Discovered by William Herschel in 1784, this object is small and dim, a 10th-magnitude blob some 3.6' across. When I observed NGC 5694 with my 12.5-inch and 16-inch reflectors, I detected no resolution even at high powers.

Moving north eastward near the Virgo/Libra border, we come to the only deep-sky object that isn't a galaxy in the region. NGC 5634 is a magnitude-9.6 object measuring 4.9' across. With a 16-inch scope it appears to be composed of an unimpressive sprinkling of very faint stars at its extremities. After a long evening winding through Virgo's countless dim galaxies, you'll find this cluster a real treat for finishing off the night.

Farther east in Libra lies the loosely structured and distant NGC 5897. This cluster shines at magnitude 8.6 but is so spread out it ap-

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I suggest that anyone interested in this strange universe in which we live read this book (skipping the last chapter). It is a succinct assessment of the current status of cosmology and an excellent preparation for the coming era of the *Hubble Space Telescope*. I suspect, however, that much of what Parker has written (what we *all* have written, for that matter) will have to be revised in the years following the deployment of the *Space Telescope*. As you read *Creation*, you would do well to keep in mind the words of H. L. Mencken: "For every problem, there is a solution that is simple, elegant, and wrong." — *George F. Benedict, University of Texas*

KEEPING TABS ON ASTRONOMY

Annual Review of Astronomy and Astrophysics, volume 26, edited by Geoffrey Burbidge, David Layzer, and John G. Phillips, (Annual Reviews, 1988), ISBN 0-8243-0926-X, hardcover, 703 pages, $47.

Want to know what's going on in astronomical research? By paging through the *Annual Review of Astronomy and Astrophysics*, published each year by Annual Reviews, you can see which areas of research are currently of great interest to professional astronomers. Each book contains twelve to fifteen articles that deliver sweeping, technical reviews of a particular topic, summarizing what is currently known and where future research is likely to take us.

Customarily the *Annual Review* begins with a personal, philosophical look back by a distinguished astronomer. William W. Morgan, the great stellar spectroscopist, describes his work and the evolution of astronomy over his lifetime in the opening of this year's volume. Along with Philip C. Keenan, Morgan developed the standard scheme for classifying stars by their spectra. Other recent contributors have been William H. McCrea, A. E. Whitford, and Jesse L. Greenstein.

The heart of the book, however, is composed of research papers. These papers give you a real sense of the cutting edge of astronomical research. Kitt Peak's Jay Frogel, for example, describes in minute detail the current state of the galactic center, or more precisely the galactic nuclear bulge. We learn that "the part of the Galaxy we call the bulge is a transition region between the young active nucleus and old metal-poor spheroid." After filling in the details of a model of the galactic center, Frogel makes it clear that there is plenty of opportunity for future astronomers in this research area.

Herbert J. Rood's synopsis of extragalactic voids provides an excellent overview of the subject. Rood, who helped develop the Rood-Sastry classification scheme for galaxy clusters, gives the reader an overview of what voids are and why they should exist between clumps of matter in the universe. Rood then explains how computer analyses of galaxy surveys show where voids exist. You come away with the impression that in the future computers will play an increasingly important role in the study of the large-scale structure of the universe.

Thirteen more papers cover topics such as astrometry, the luminosity function of galaxies, comets, the origin of the solar system, and the variability of the Sun's energy output.

The *Annual Review* is a big, meaty package written in specialized, technical language. The book contains information of great interest to amateur astronomers, but it also carries a hefty price tag. If you don't want to buy the book, seek it out in a library. You'll enrich your knowledge of what astronomy is all about and where it's going in just a few hours of reading. If you're interested in professional astronomy, it's one of the best deals around. — *David J. Eicher*

ASTROPHYSICS

Molecular Clouds in the Milky Way and External Galaxies, edited by R. L. Dickman, R. L. Snell, and J. S. Young, (Springer-Verlag, 1988), ISBN 0-387-50438-9, hardcover, 475 pages, $50.50.

Multiwavelength Astrophysics, edited by France Cordova, (Cambridge University Press, 1988), ISBN 0-521-36197-4, hardcover, 400 pages, $59.50.

QSO Absorption Lines: Probing the Universe, edited by J. Chris Blades, David A. Turnshek, and Colin A. Norman, (Cambridge University Press, 1988), ISBN 0-521-34561-8, hardcover, 348 pages, no price given.

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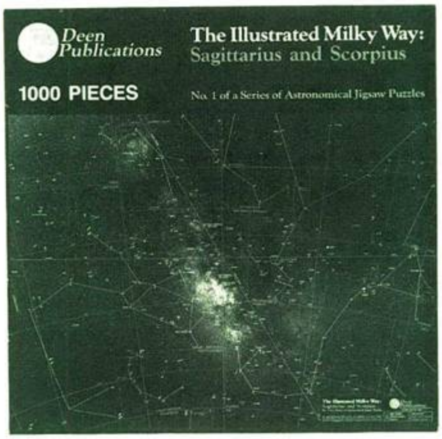
PIECING TOGETHER THE MILKY WAY

The Illustrated Milky Way: Sagittarius and Scorpius, (Deen Publications, P.O. Box 831991, Richardson, TX 75083-1991), 20-by-27 inch, 1,000-piece jigsaw puzzle, $12.95.

This was a lot of fun. As a novice puzzle-worker, I sat down to assemble this thing with two expert puzzlers who knew nothing about astronomy.

The picture is a color photograph centered on the heart of the Milky Way in Sagittarius. Taken with a wide-angle camera on roll film (20-minute exposure on hypered 120-format Fujichrome 100 developed as a negative, using a 45mm lens at f/4), the photo itself is a piece of art. Printed into the photo are a coordinate grid and the names of 170 stars and hundreds of deep-sky objects.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The Illustrated Milky Way: Sagittarius and Scorpius
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A "PUZZLING" MAP that shows the heart of the Milky Way.

When I first told my fellow-puzzlers about it, they were dubious: "What? A picture of stars? You gotta be kidding!" But after seeing the photo on the box cover, they agreed to help.

Constellation stars are connected by blue lines, while the coordinate grid is in green, the galactic equator is in yellow, and the ecliptic is in red. Star names and designations are in white, and deep-sky objects are color-coded by type: yellow for open and globular clusters, red for galaxies and dark nebulae, and green for diffuse and planetary nebulae. The photo was taken August 15, 1987, so Saturn, Uranus, and Neptune all lie in the field and are identified.

Putting it together was a lesson in the technique of puzzling. One of the experts started pulling border pieces together, while the other laid them all out so he could see what each showed. I started picking out pieces with the galactic equator on them, and when I finished that, I began on the ecliptic.

By then the experts had enough of the border together to show where the right ascension and declination lines went. Then I started looking for pieces with NGC and IC objects on them. The designations increase with right ascension, so I always had a pretty good idea where they went.

This drove them nuts. "How do you *know* that piece goes there?" they demanded when I put a piece down in the middle of a large open area and announced it belonged there. Eventually, though, all the "identified" pieces were in place — and the experts exacted their vengeance. All that was left were unmarked pieces of anonymous starfields. As I stared helplessly, they snapped up piece after piece, working by shape and some kind of occult puzzler's instinct.

The two experts claimed this was a really odd puzzle because the border pieces were tough to pick out. Instead, they noted, you begin this puzzle on the inside with the galactic equator and work your way out from there.

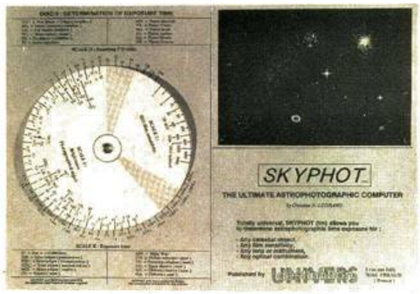
The box says this is the first of a series and hints that others will explore different parts of the Milky Way. Being a galaxy observer, I'd love to see a rich cluster puzzle — anybody for Coma-Virgo? — *Robert Bunge*

OBSERVING ACCESSORIES

***Skyphot* Astrophotographic Exposure Calculator** by Christian D. Legrand, (Destination Universe, 5 rue aux Juifs, 76160 Preaux, France), 70 francs (about $12), air mail postage included.

The *Skyphot* exposure calculator consists of a two-leaf heavy paper folder measuring about 6 inches by 8¼ inches that contains three dials turning on rivets. The first dial lets you calculate the actual f/ratio for any astrophotographic system, and the second combines the angular size and photographic magnitude of an object into an "object brightness" measure. The third dial rolls together f/ratio, film speed, and object brightness to yield the nominal exposure time. The instructions for *Skyphot* note that you should bracket this exposure with two others, one stop over and one under.

All the instructions and the legends on the dials are in English, and the device is easily usable under red light.



DETERMINING EXPOSURES in astrophotography becomes easier with *Skyphot*, a calculator that combines effective f/ratio, film speed, and object brightness to yield a basic exposure time for any camera system.

OBSERVING AIDS

Starwatcher's Decoder Set, (Bausch & Lomb, 1988), $34.95.

Aimed at beginners who want to learn the constellations, this kit contains a plastic frame you hold up to the sky with transparent insert sheets that show the stars and constellations. Its goal is to span the gap between the starry sky (which has no labels whatever) and the pages of the typical star chart or atlas, which to beginners often seem confusingly overcrowded with labels.

The kit, which is based on the "Star Frame" idea devised by Ben Mayer (and popularized in his book *Astrowatch*), also includes a square of red cellophane to go over a flashlight lens and several blank transparent sheets so you can make your own "Star Frames." ☐

STAR MAPS held up to the sky in a plastic frame can help beginners learn the major constellations.

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Meetings and Events

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9th Annual Summer Telescope Demonstration and Star Party, Oceanside, California. Contact: Penny Hauck, 1024 Mission Avenue, Oceanside, CA 92054.

May 24-26
1989 I.A.P.P.P. Big Bear Symposium, Big Bear Lake, California. Contact: Roger DeYoe, 3416 Genevieve Street, San Bernardino, CA 92405. Phone: (714) 883-9807.

May 26-29
Riverside Telescope Makers Conference, Camp Oakes, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Avenue, Riverside, CA 92503. Phone: (714) 689-6893.

May 27
Astronomy Day, New Mexico Museum of Natural History, Albuquerque, New Mexico. Contact: Bruce L. Levin, P.O. Box 54072, Albuquerque, NM 87153. Phone: (505) 299-0891.

May 29-June 4
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: T.S.P. Registrar, Bobby Braley, Department "A," P.O. Box 386, Wylie, TX 75098.

June 2-4
Astronomy Weekend '89, Martz Observatory, Frewsburg, New York. Sponsored by the Marshal Martz Memorial Astronomical Association. Contact: Liz Kalas, R.D. #1, Box 1127, Russell, PA 16345. Phone: (814) 757-9266.

June 2-4
Front Range Super Cluster Star Party, Medicine Bow Forest, Wyoming. Sponsored by the Denver, Longmont, Boulder Valley, Colorado Springs, and Cheyenne astronomical societies. Contact: Marcy Flint, 3409 Frontier Street, Cheyenne, WY 82001. Phone: (307) 632-2717.

June 9-10
19th Annual Apollo Rendezvous and Telescope Fair, Dayton, Ohio. Sponsored by the Miami Valley Astronomical Society and the Dayton Museum of Natural History. Contact: Ian Dumbauld, MVAS, 2629 Ridge Avenue, Dayton, OH 45414. Phone: (513) 837-4600.

June 16-18
14th Annual Meeting of the Association des Groupes d'Astronomes Amateurs, Laval, Quebec. Contact: Congress '89, A.G.A.A., P.O. Box 1000, Station M, Montreal, Quebec, Canada H1V 3R2. Phone: (514) 625-5527.

June 21-25
Centennial Meeting of the Astronomical Society of the Pacific, University of California at Berkeley. Contact: Berkeley Meeting Information, A.S.P., 390 Ashton Avenue, San Francisco, CA 94112.

June 23-24
4th Annual Sedona-Verde Valley Astrophotography Festival: Milky Way Galaxy, Verde Valley Preserve of Thousand Trails, Arizona. Contact: Russell A. Nidey, Verde Valley Astro-Center, 1101 Zalesky Road, Cottonwood, AZ 86326.

June 24
Annual Summer Solstice Celebration and Star Party, East Detroit, Michigan. Contact: Alan Rothenberg, P.O. Box 474, East Detroit, MI 48021. Phone: (313) 344-2854.

June 24
The Great Snowball Melt, Discovery Center, Syracuse, New York. Contact: Stephen A. Karon, 321 South Clinton Street, Syracuse, NY 13202. Phone: (315) 425-9068.

June 27-30
1989 Biennial Meeting of the Planetarium Association of Canada, Montreal, Quebec. Contact: Nicole Patenaude, Planetarium Dow, 1000 rue Saint-Jacques ouest, Montreal, Quebec, Canada H3C 1G7. Phone: (514) 872-4530.

June 30-July 2
Astronomical League Mid-States Regional Convention, Tulsa, Oklahoma. Sponsored by the Astronomy Club of Tulsa. Contact: Newel Pottorf, 3832 South Victor, Tulsa, OK 74105. Phone: (918) 742-7577.

July 1
Star Bash, Huntsburg, Ohio. Sponsored by the Chagrin Valley Astronomical Society. Contact: Don Himes, P.O. Box 11, Chagrin Falls, OH 44022. Phone: (216) 247-5114.

July 1-31
Moon-Moonta, West Palm Beach, Florida. Contact: Gary Bogner, 4801 Dreher Trail North, West Palm Beach, FL 33405. Phone: (407) 832-1958.

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information. □

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FOR SALE – ASTRONOMY. May 1975-May 1987. *Sky & Telescope*. Miscellaneous issues. McGraw-Hill Contemporary Electronics Series including tutorials, tapes, and hardware. Contact Rick A. Poop, 6346 Uncle Remus #2, Memphis, TN 38115. Phone (901) 368-4919.

FOR SALE – 17.5" Odyssey 2 reflector with two eyepieces. Brand new, perfect condition. $1,000. Will deliver within one hundred miles. Contact Bill Stegeman, 5 Meadow Wood Lane, Landenberg, PA 19350. Phone (215) 255-0413.

FOR SALE – 20mm Meade wide-angle eyepiece, 26mm Plossl, 40mm Kellner, 18mm Kellner, 1.25" eyepieces, and 1.25" Barlow. All for $150 plus shipping. Contact Carol Nelson, Bow Lake Road, Barnstead, NH 03218. Phone (603) 269-3368 (evenings).

FOR SALE – C11SB, wedge, tripod, Accutrak 4402, f/7.5 and f/5 comp., RFA, extender, off-axis guider, and 10x70 finder. No eyepieces. Make offer, buyer pays shipping. Phone (307) 473-1310.

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Readings and Resources

Earth's Early History (page 24)

Origin of the Moon, edited by William K. Hartmann, R. J. Phillips, and G. J. Taylor, (Lunar and Planetary Institute, 1986). Although this book is aimed at planetary scientists, it contains many review papers that are accessible to laymen.

The Planetary System by David Morrison and Tobias Owen, (Addison-Wesley, 1988). An up-to-date and readable survey of planetary science.

Moons and Planets by William K. Hartmann, (Wadsworth Publishing, 1983). A survey of planetary science emphasizing the processes by which things happen.

How Far? (page 48)

Galaxies by Paul Hodge, (Harvard University Press, 1986). The chapter "The Distance Scale" is an excellent overview of the problems with and progress in establishing extragalactic distances.

The Extragalactic Distance Scale, edited by Sidney van den Bergh and Christopher J. Pritchet (Astronomical Society of the Pacific, 1988). A technical look at the latest information from the key researchers in the field.

Astrophotography Success (page 68)

Astrophotography for the Amateur by Michael Covington, (Cambridge University Press, 1985). An excellent intermediate-level guide to photographing all of the sky's wonders.

Behind Saturn's Rings (page 80)

Rings: Discoveries from Galileo to Voyager by James Elliot and Richard Kerr, (MIT Press, 1984). The accounts of previous stellar occultations of Saturn in chapter two give information on what to expect from the upcoming occultation.

Dusty Dark Nebulae (page 86)

Atlas of Selected Regions of the Milky Way by Edward Emerson Barnard, (Carnegie Institution, 1927). The classic, two-volume work on dark nebulae.

Backyard Observatory (page 90)

How to Build Your Own Observatory, edited by Richard Berry, (Kalmbach Publishing Co., 1988). Seventeen articles reprinted from *Telescope Making* magazine describe techniques for building a variety of home observatories.

Building Small Barns, Sheds, and Shelters by Monte Burch, (Garden Way Publishing, 1983). How-to tips and detailed diagrams on constructing small buildings.

Basic Carpentry by John Capotosto, second edition, (Reston Publishing Co., 1980). A basic course in carpentry techniques.

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COMING IN THE JULY 1989 ISSUE OF ASTRONOMY

SPECIAL ISSUE: 20TH ANNIVERSARY OF **APOLLO 11**

- ***One Small Step . . .*** The *Apollo* astronauts recall what it was like to journey to and walk on the Moon.
- ***Will We Go Back?*** A look at current ideas and plans for returning permanently to the lunar surface.

AVAILABLE ON YOUR NEWSSTAND JUNE 13

READER EXCHANGE

ANNOUNCEMENT – The Jackson Astronomical Society meets the first Friday of each month at 7:30 p.m. at the Salvation Army Headquarters building on Riverside Drive. Guests welcome. Club has a dark site for members. Contact JAA, 414 Woody Drive, Jackson, MS 39212. Phone (601) 372-2275.

ANNOUNCEMENT – The Harford County Astronomical Society meets the first Friday of each month at 8 p.m. at the Harford Community College, Joppa Hall, Room J-70, Bel Air, Maryland. Membership open to all. Contact membership chairman Paul Edmiston at (301) 836-2179.

ANNOUNCEMENT – Free astronomy software for IBM and compatibles. Over two hundred astronomy and space science programs available from NASA, JPL, academic, scientific, space industry, public domain, and shareware sources. Send SASE. Contact Joe Dumanov, 55 Hillside Road, Sparta, NJ 07871. Phone (201) 729-9508.

ANNOUNCEMENT – The Syracuse Astronomical Society will host its nineteenth annual NFCAAA summer seminar at the Darling Hill Observatory in Vesper, New York, July 28-30. Free campsites are available on a first-come, first-served basis. Contact Rod McCabe, 706 Campbell Road, Mattydale, NY 13211. Phone (315) 454-3150 (evenings and weekends).

ANNOUNCEMENT – The Link Planetarium/Kopernik Observatory has a planetarium internship available. The eleven-month appointment begins September 1, 1989, and has a $10,000 stipend, plus bonuses for public courses. Qualifications are a BA/BS in science or education and some planetarium or museum experience or equivalent. Contact William Buckingham, Link Planetarium, 30 Front Street, Binghamton, NY 13905.

FOR SALE – Celestron Comet Catcher with 18mm eyepiece. Worth $700, asking $450. Contact Ted Senior or Forrest Senior, 2105 Mozart Street, Tell City, IN 47586. Phone (812) 547-6055.

FOR SALE – Celestron Comet Catcher. $300, buyer picks up. Also, meteorites and photographs wanted for scientific research. Contact Christopher E. Spratt, 314-2100 Granite Street, Victoria, British Columbia, Canada, V8S 3G7. Phone (604) 592-6079 (evenings).

FOR SALE – Odyssey 1 13.5″ telescope. Used once. $650 plus shipping. Phone Terry at (606) 878-8427.

FOR SALE – Telescopics sky micro regular 1-1/4″ focuser. $30. Telescopics 3/4″ diagonal. $10. 2″-diameter f/4 objective. $12. 24″ by 5″ aluminum tube. $5. Contact Gary R. Phelps, 226 High Avenue, Oshkosh, WI 54901. Phone (414) 233-1699.

FOR SALE – 6″ f/8 Cave Student Deluxe Newtonian reflector with excellent optics, German equatorial mount, clock drive, setting circles, and two eyepieces. $300. Contact Dan Boyar, 712 SW 3rd Avenue, Boynton Beach, FL 33426. Phone (407) 737-3958.

FOR SALE – Celestron Super C8 with Starbright coatings, 8x50 finder with illuminated eyepiece, 26mm Plossl, 7mm Ortho, tripod with Byers sidereal rate drive system, Meade T-adaptor, and tele-extender. Brand new. $900 plus shipping. Contact Joseph M. Getcy, 16 Livingston Court, Staten Island, NY 10310. Phone (718) 273-7461.

FOR SALE – Astroscan telescope with three eyepieces, image erector, tripod bracket, owner's manuals, and Burnham's *Celestial Handbook*. $400. Bogen professional tripod. Used six times. $150 postpaid. Contact Nan Essler, Route 1, Box 185-D, Empire, MI 49630. Phone (616) 326-5148.

FOR SALE – 4.8mm Tele Vue Nagler. $85. 9mm and 25mm Meade MA eyepieces. $50 for both. 20mm research-grade Meade eyepiece. $25. Meade #80A color filter. $10. All in excellent condition. Will pay shipping. Contact Thomas Watson, 704 Ballywood Road, Irving, TX 75060. Phone (214) 579-0947 (afternoons).

FOR SALE – C8 with adjustable tripod, wedge, off-axis guider, sliding and fixed counterweights, dual-axis corrector, custom adjustable tangent coupler for guidescope, tele-extender, RFA, and more. Fully equipped. Extras. Will deliver in southern California. $1,500. Phone (619) 948-4283.

FOR SALE – 3″ f/16 Unitron refractor with Unihex eyepiece holder with R25mm, K18, K12.5, 9 Sym Ach, 6 Ortho, Sun projection filter, finder, caps, tripod legs and shelf, and cradle. No equatorial mount. $350. Contact 5123 Felicia Avenue, Livermore, CA 94550. Phone (415) 449-7721.

FOR SALE – ASTRONOMY. March 1976-October 1980, December 1980-March 1984, and May 1984-April 1985. $50. Contact D. Willis, 402 30th Avenue North #13, Fargo, ND 58102. Phone (701) 293-7188.

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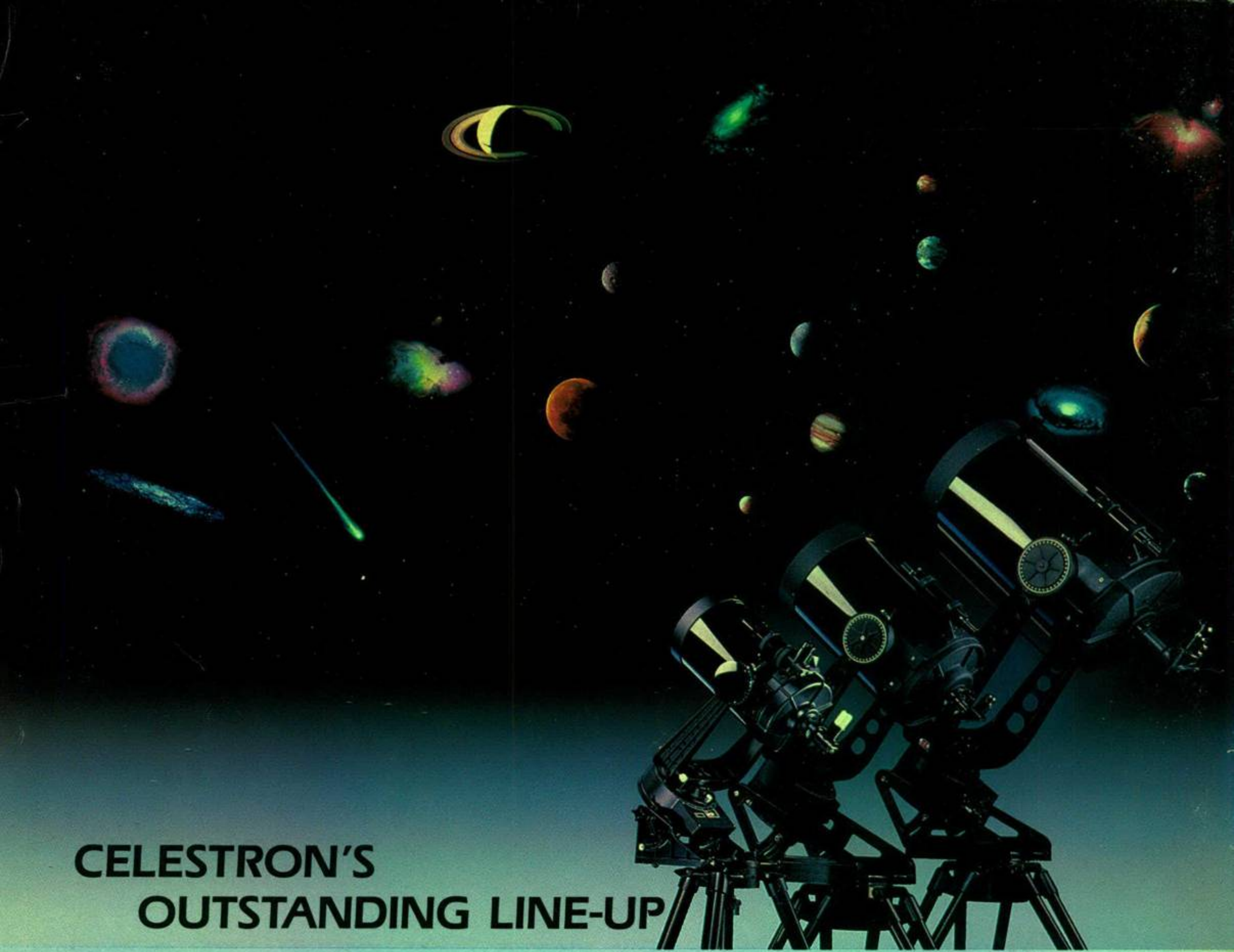

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For the ultimate in catadioptrics, look to Celestron. Available in 8″, 11″ and 14″ models, these premier instruments deliver much needed stability, superior optical performance, the finest coatings, and the finest drive systems. Inch for inch, these Celestron systems far outshine the competition.

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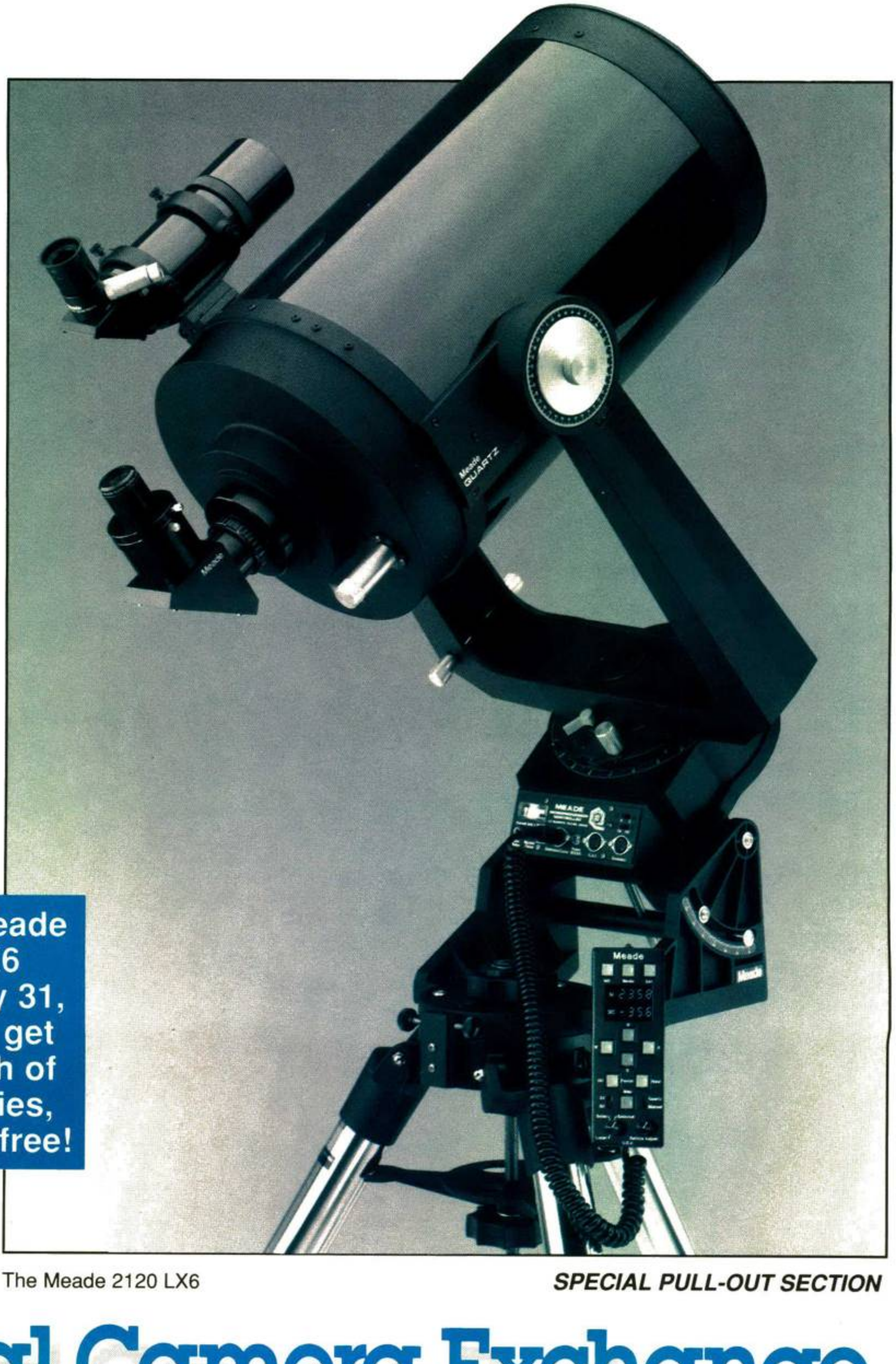

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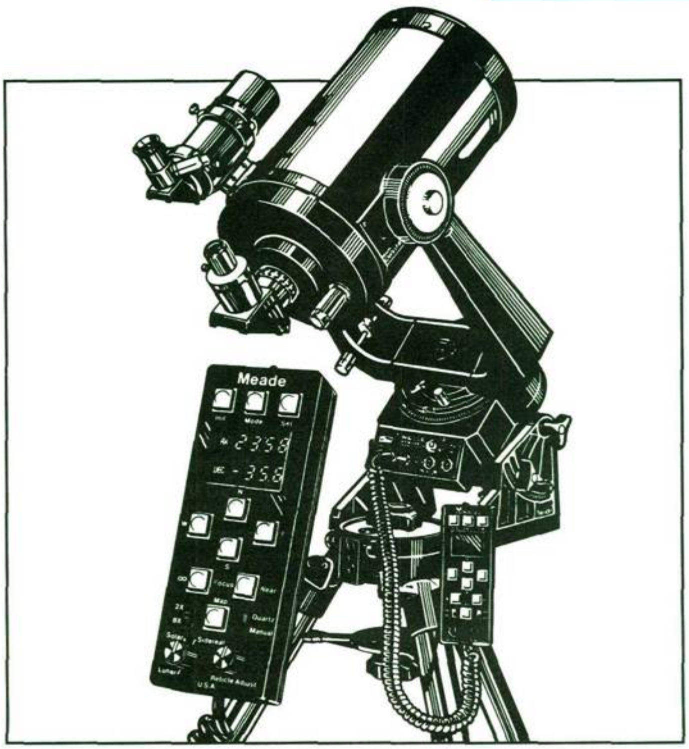
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Meade Instruments and National Camera Exchange offer you an exciting astronomical package, designed for incredible viewing and unsurpassed astrophotography. The Meade 2120 LX6 is the ideal telescope to explore and photograph the vast night sky. Buy before May 31, 1989, and get $750 in accessories, ***absolutely free!***

Using the latest technology, Meade has produced a quality 10 inch Schmidt-Cassegrain tube with the fast focal ratio necessary for short photographic exposure times, and bright, wide-field viewing.

The 2120 LX6 produces spectacular images and allows quick exposure times, like the more cumbersome Newtonian styles. Yet, it has the portability and ease of use of a Schmidt-Cassegrain. With this fine telescope, you'll get a 59% increase in the field of view, and a 60% decrease in exposure times when compared with conventional f/10 Schmidt-Cassegrains. Virtually all possible detail of the Orion Nebula is shown with just a 5 minute exposure. Plus, by using a system of computer optimized ultra-high contrast baffling, it maintains crisp imaging for lunar and planetary observation. With the Meade 2120 LX6, nothing is compromised.

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You'll also get the quartz microprocessor controlled electronic drive system, a Meade exclusive. The RA pulse motor and worm gear system allows true sidereal-rate tracking accurate to .005%, and variable rates for lunar, solar, or planetary motion. This feature is critical in following day-to-day changes in sunspots or the changing seasons of Mars.

The base is designed to accept a variety of important accessories, such as the electronic focuser, the declination motor and the new Meade Digital Readout System. All can be controlled with the Electronic Command Center, which is included with the 2120 LX6. The Command Center also provides bi-directional 8-power slewing for high power scanning and easy positioning of your telescope, plus 2-power guiding speed for astro-photography. A red map light is attached to the control, for comfortable star chart reading.

National Camera Exchange has teamed with Meade to give you a great buy on both the 2120 LX6 and 2080 LX6. Purchase either telescope by May 31, 1989, and Meade will send you these ***free*** accessories...

- Meade Series 4000 6.4mm Super Plossl eyepiece
- Meade Series 4000 18mm super wide angle eyepiece
- Meade Series 4000 #140 2X Barlow
- Four 1.25 inch color filters (one each red, yellow, blue, and polarizer)
- #62 camera adapter
- tele-extender for eyeiece projection photography
- foam lined deluxe metal accessory case
- 24-page star chart

That's a retail value of over $750, and it's yours ***absolutely free*** when you buy a 2120 LX6. We'll ship your order anywhere in the continental USA (excluding Alaska), at no additional charge! (Others please call or write for shipping charges). As with all orders, you'll get our no-risk guarantee. Order today, by calling our toll-free number below!

TO ORDER CALL TOLL-FREE 1-800-624-8107

THE MEADE 2080 SCT $999

For a limited time, Meade has re-introduced the basic 8 inch f/10 Schmidt-Cassegrain telescope with a standard worm-gear drive! Include the optional Multi-Coated Optics Group and increase your light gathering capacity by approximately 20%. Purchase now, and for a limited time you'll receive the National Camera Exchange SCT special...free! That's a $100 value free with the mention of this ad.

The Meade 2080 SCT offers the superb optics of a quality Meade Schmidt-Cassegrain with the accuracy of a worm gear drive... for consistant, stable tracking.

Its features include...

- 6x30 straight finder
- AC power cord
- setting circles
- manual slow motion controls
- 25mm/80 power modified achromatic eyepiece

You'll also get Meade's sturdy equatorial wedge and a variable height tripod. It's a complete working system for visual and astrophotographic use.... offered to you by Meade and National Camera Exchange for $999. A great value!

Suggested Accessories

Meade #62 T-adapter	**$35**
Meade #712 Dew Shade	**$59**
Meade #1A Dust seal filter	**$49**
Meade Series 6 drop-in filter set	**$59**
Muirden's How to Use and Astronomical Telescope	**$24**

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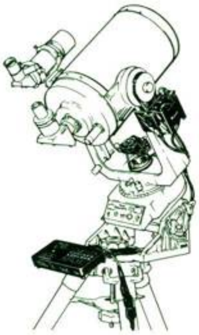

Developed by Advanced Technology Instruments and improved by Meade for even better performance! The CAT is a sophisticated computer accessory that attaches to your Schmidt-Cassegrain telescope and leads you from object to object in the night sky.

Its microcomputer memory contains more than 8000 objects, including the entire Computerized New General Catalogue (CNGC), the Messier catalog, and the STAR Catalog of notable stars. In addition, Meade has enhanced the information, so star charts are seldom needed. The CAT teaches you the sky by displaying the coordinates, type, magnitude, size, and visual quality of each object.

The CAT control board is straightforward and easy to use, with all commands and functions clearly printed on the console. With brief familiarization, you can key in the information to find any object. Then move the telescope until the center square of the "red cross" is illuminated. The "red cross" display is a graphic display of the direction and distance to your selected object, and acts as a "bulls-eye" for target location.

Several functions of the CAT assist varying astronomy needs. Polar align accurately, find difficult deep-sky objects, identify other unknown systems, compare several similar objects, or search the skies for comets. All can be done quickly and accurately with the CAT system.

Includes control console, right ascension and declination encoders, AC and DC power cords, detailed instruction manual, and all hardware to mount to most Meade or Celestron Schmidt-Cassegrain telescopes (please specify brand, model and year manufactured).

ASK ABOUT OUR $100 INSTANT REBATE!

THE MEADE DIGITAL READOUT SYSTEM $399

Make your viewing faster, more convenient, and more fun with the Digital Readout System. Easily installed to your telescope, the DRS gives you local and sidereal time, declination and right ascension coordinates, frequency of the motor's input current, and digital timing for your astrophotographs. All information is displayed for easy accessibility, and makes finding objects faster and easier with an accuracy of almost 5 times above conventional setting circles. Add the advanced Digital Setting Circles for a versatile, easy-to-use system.

TO ORDER CALL TOLL-FREE 1-800-624-8107

Photos by Tom Orzechowski

ASTROPHOTOGRAPHY

Although your telescope has revealed a whole new dimension of the sky, you may have found a limitation. Your eye gathers a small amount of light, when compared to the light emitted by billions of stars, nebulae and other systems. Many objects lie beyond our visual capacity, and you can experience much more of the deep sky by venturing into astrophotography.

Equipment

Exciting astrophotography can be easily done with a standard 35mm single-lens reflex (SLR) camera. Many of today's cameras feature advanced electronics, but the best astrocameras have a mechanical bulb (B) setting. This allows the shutter to be locked open for long exposures without draining the camera battery.

Attach your camera directly to the telescope for high power photography. Or add an eyepiece to the system for much higher magnification. For wide-field photographs, use standard lenses available for your camera. Fast aperture, fixed focal length lenses are preferred over slower zoom lenses.

Examine some of the more advanced accessories that can enhance your astrophotography. Choose a filter to increase contrast, saturate color, or to transmit only the light you want the camera to see. Hypersensitize your film to increase its ISO rating. All will dramatically enhance your final images.

Astrophotography Tips

If you are new to astrophotography, start with simple low power objects. For good results right away, try photographing the moon. Its intense brightness yields fast exposure times and sharp pictures.

Piggyback photography expands your possibilities. In mounting your camera to a clock-driven telescope, the scope is used only as a drive mechanism to freeze the "motion" of the stars and record them on film. Try different lenses from 50mm normal to long telephoto. Be certain to accurately polar align your telescope.

Higher power photography requires greater precision. Atmospheric changes, errors in alignment, and other factors force you to guide the telescope for sharp images. A high power guidescope will help you stay pinpointed on a guide star as you make fine corrections to the drive rate with a remote hand control.

With practice and patience, you can take outstanding astrophotographs. Keep detailed records of every shot to accurately gauge the best exposures. The more you experiment and analyze the results, the better your pictures will be.

MEADE MTS-SN6 WITH MCOG SYSTEM

$739

Now a complete telescope with AC drive system, setting circles, and Multi-Coated Optics Group (MCOG). This 6" f/5 telescope offers superb wide-field viewing, or astrophotography in short exposure times. Features fork-mounted optical tube with 2" helicoid focuser, 1.25" 25mm eyepiece, equatorial pier mount with latitude scale, drive system, AC power cord, and MCOG.

MEADE DS-16A

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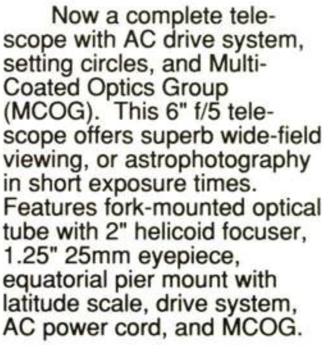

Meade Deep-Space telescopes are amazingly versatile large aperture telescopes at a low price. With sturdy pier-type equatorial mounts, precision setting circles, and accurate clock drive systems, the DS-16A and DS-10A telescopes offer much greater flexibility than standard Dobsonian reflectors. Diffraction limited optics allow critical observation, and with fast focal ratios (16" f/4, 10" f/4.5), Deep-Space telescopes are great for advanced astrophotography. Includes Sonotube with giant focuser, 25mm eyepiece, equatorial mount, AC clock drive, and setting circles. DS-16A shipped Truck Freight Collect.

MEADE DS-10A

$949

CHOOSING THE RIGHT EYEPIECES

No matter which telescope you own, the eyepiece is the most important link to the sky, and many types are available.

Magnification

The highest **useful magnification** of a telescope is fifty times the aperture in inches. An 8" telescope requires optimum viewing conditions close to its maximum useful magnification of 400X. The minimum useful magnification is about four times the aperture, or 32X for an 8" telescope.
To calculate real magnification, use this equation:

$$m = \frac{\text{focal length of telescope}}{\text{focal length of eyepiece}}$$

A 2000mm Schmidt-Cassegrain telescope with a 25mm eyepiece will yield an 80X magnification. A larger eyepiece yields a lower power (2000÷50=40X), and smaller eyepiece yields a higher magnification (2000÷10=200X).

Field of View

Eyepieces determine your telescope's magnification and field of view. **Apparent field** is the viewing angle defined by the eyepiece. Inexpensive eyepieces often have an extremely narrow apparent field which makes them difficult to use, especially at high powers. Better eyepieces reveal a wider field at the same power and offer more 3-dimensional viewing.

True field refers to the actual area of the sky that you see. To capture more light in viewing faint nebulae, choose a low power and wide true field. A higher power, wider apparent field eyepiece may show a similar true field, but its high contrast may obscure faint details.

For viewing **deep sky** objects, use your telescope at low to medium power, and choose a wide field of 65° to 70° that is sharp to its field edge. For the sharpest, widest field, try a large 2" eyepiece.

If **planets** are your interest, the narrower 50° to 55° field of a Plossl will best portray these bright objects. A good Barlow lens will increase power, improve sharpness across the field, and give longer eye relief.

For best contrast and dark skies, use an ultra-wide 80° to 85° eyepiece. It will transmit the sharpest image with a 3-dimensional wide apparent field.

ALL EYEPIECES

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MEADE SUPER PLOSSL EYEPIECES

At these prices, you can step up from your current standard eyepieces. The Meade Super Plossl offers a noticeably sharper view than oculars that come with most telescopes. Their 52 degree apparent field is 20% to 50% wider than many factory eyepieces. The fully multi-coated five element design ensures a breathtaking sky image. View the largest actual field with the 2" diameter 56mm. Or try higher powers with the 1.25" 40mm to 6.4mm eyepieces. Even telescopes using smaller diameter eyepieces can be improved with the addition of a .965" adapter.

56mm Super Plossl	**$158**
40mm Super Plossl	**$93**
32mm Super Plossl	**$93**
26mm, 20mm, 15mm, 12.4mm, 9.7mm, 6.4mm Super Plossl	**$73**

MEADE SERIES 4000 BARLOW LENSES

Magnify your power by 2x with this three-element, air-spaced Barlow lens. When used with any eyepiece, eye relief is increased and field sharpness is much flatter. Adding one Barlow lens effectively doubles your eyepiece collection. Fully multicoated.

Series 4000 #140 2x	**$70**

MEADE ULTRA WIDE ANGLE EYEPIECES

View deep black skies and crystaline star points with these ultra wide 84 degree apparent field eyepieces . Life-like star fields pop into focus and seem within your grasp. Sharp images across the entire field. The 14mm and 8.8mm fit both 1.25" and 2" focusers, the 6.7mm and 4.7mm are 1.25". All eyepieces are fully multicoated.

14mm Ultra Wide	**$214**
8.8mm Ultra Wide	**$197**
6.7mm Ultra Wide	**$158**
4.7mm Ultra Wide	**$138**

MEADE SUPER WIDE ANGLE EYEPIECES

Nearly 70% more field area than the Super Plossl. These 67 degree apparent field eyepieces are great for fast reflectors, where many eyepieces show their true nature. Fully multicoated for true color rendition and optimum light transmission. Provides excellent eye relief for eyeglass wearers. The 40mm and 32mm have 2" barrels and the 24.5mm, 18mm and 13.8mm are 1.25".

40mm Super Wide	**$248**
32mm Super Wide	**$196**
24.5mm Super Wide	**$138**
18mm Super Wide	**$128**
13.8mm SUper Wide	**$118**

TIPS FOR BETTER VIEWING

Good seeing is vital to proper telescope performance and full delineation of stellar objects. High power viewing (100x-400x+) especially demands great skies. Light pollution, air-borne particles, atmospheric refraction, and other atmospheric effects determine the power you will use on a given viewing night. Use low power (20x-50x) when these factors appear.

For the best observation of an object look as high in the sky as possible. Looking straight up means looking through less of the Earth's atmosphere and better resolution.

Pre-plan some of the objects that you will look for on any viewing night. A good **star atlas** will show great detail and help you to pick out objects more easily. Use it in conjuction with a **planisphere** to plan the location of your object at a convenient time, in an accessible area of the sky.

For better night vision, allow proper **dark adaptation** of at least thirty minutes without white light to realize your eye's full capability. And use a red-filtered flashlight when using star charts in the field. When searching for extremely dim objects, use averted vision with the more sensitive outer areas of the retina to pull them in.

For easy location of objects, properly align the **finderscope** to the view seen through your telescope. Find an object through the telescope at low power and center the image on the crosshair of the finder. To fine tune this alignment, switch to a higher power eyepiece and do the same.

Proper **filtration** can help you cut through unneeded bands of light to fully reveal intricate details. Use a polarizer for moon viewing, or two together for variable density control. Color filters provide both color enhancement and detail observation of planets when used properly. Look for other more specialized filters when studying reflection or emission nebulae, galaxies, or chasing comets.

Improve extended viewing of any object by using a **clock drive** with the telescope. Your eye concentrates easily on an object when not tracking a moving point of light through the eyepiece. For this same reason, a **remote focus motor** is also an added benefit. The best viewing tip is to invest in high quality eyepieces.

TRADE IN

TRADE UP!

CELESTRON SUPER POLARIS C8 STARBRIGHT

$1079

Perfect for advanced visual work and adaptable for astrophotography. The Super Polaris C8 is still at our low 1988 price and features enhanced Celestron Starbright coating and the legendary Super Polaris mount. With worm- gear manual controls for both axis', and easy-to-read setting circles, this 8" is easily positioned on the sturdy mount. With the addition of the optional Sky Sensor computer, your SP-C8 will locate deep sky objects, track the stars and allow fine correction for astrophotography. Includes 26mm Plossl eyepiece, star diagonal, 6x30 finderscope, Super Polaris mount, polar axis finder, hardwood tripod and case.

CELESTRON FIRSTSCOPE 80

$499

Ideal for easy object location for the more casual viewer....just point and view! This 3" refractor is supported on a simple altazimuth mount and sturdy adjustable tripod. The altazimuth mount allows quick and easy telescope orientation for both land and sky observation. The slow motion controls keep your object centered. Features 910mm f/11 achromatic objective. Includes 18mm Ortho eyepiece, 45 degree erecting prism, 6x30 finderscope, accessory tray, and adjustable tripod.

CELESTRON C4.5

$469

View countless deep sky objects, or study lunar and planetary details with this versatile 4.5" f/8 reflector. A great starter telescope for beginners, but well constructed for the serious amateur. Features fully multicoated optical system, deluxe 1.25" rack and pinion focuser, 25mm orthoscopic eyepiece, 5x24 finderscope, rugged German equatorial mount, fine latitude adjuster, fine azimuth control, slow motion controls, attractive wood tripod, and accessory tray.

Optional Polar Alignment Telescope for the C4.5 **$49**

TELE VUE GENESIS

$1349

This 4", four element refractor is a compact multi-purpose telescope with contrast, field and resolution capabilities exceeding far larger instruments. It is excellent for astronomical and terrestrial use, and provides rich, wide-field views of star clusters and nebulae over a five degree flat field. In addition, the internal fluorite element used in the Genesis assures excellent color correction for high-resolution planet and double star viewing at magnifications exceeding 200x. When coupled with any standard 35mm camera, the telescope becomes a spectacular 500mm f/5 telephoto lens. The Genesis is an ideal, all-purpose portable telescope. To customize your package, we stock a variety of Tele Vue mounting systems, eyepieces and accessories.

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